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(54) **Method and device for locating RFID tags**

Verfahren und Gerät zur Ortung von RFID-Tags

Procédé et dispositif pour localiser des étiquettes RFID

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(73) Proprietor: **Siemens Aktiengesellschaft**
**80333 München (DE)**

(72) Inventors:
- **YUAN, Yong**
**Beijing 102208 (CN)**
- **YU, Dan**
**Beijing 100102 (CN)**
- **HORST, Dieter**
**90556 Cadolzburg (DE)**

(74) Representative: **Isarpatent**
**Patent- und Rechtsanwälte Behnisch Barth Charles**
**Hassa Peckmann & Partner mbB**
**Friedrichstrasse 31**
**80801 München (DE)**

(56) References cited:
**EP-A1- 1 995 683**
**WO-A1-2010/001354**
**CN-A- 101 046 843**
**CN-A- 101 853 413**
**JP-A- 2009 270 901**

- **PAVEL V NIKITIN ET AL: "Phase based spatial identification of UHF RFID tags", RFID, 2010 IEEE INTERNATIONAL CONFERENCE ON, IEEE, PISCATAWAY, NJ, USA, 14 April 2010 (2010-04-14), pages 102-109, XP031677646, ISBN: 978-1-4244-5742-7**



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## Description

### Technical field

**[0001]** The present invention relates to the field of radio frequency identification (RFID), in particular to a method for locating a tag using a radio frequency identification reader, and a radio frequency identification reader.

### Background art

**[0002]** Compared with high frequency (HF) radio frequency identification (RFID) systems, ultra high frequency (UHF) RFID has many superior properties, such as: fast tag accessing speed, cheap tags, and the ability to perform tagging at the level of individual items in both manufacturing and logistics applications. However, in view of the far-field electromagnetic transmission characteristics of UHF RFID, for instance multi-path transmission, it is difficult to maintain a controlled reading zone for UHF RFID. There may be certain reading gaps (field nulls) in the required reading zone, which make reading less reliable in that zone. Cross reading may also occur during identification of remote tags outside the zone. This lack of control over the reading zone causes major problems in manufacturing and logistics applications.

**[0003]** In manufacturing applications, the system must ascertain precisely when a tag enters the reading zone, and when it leaves the reading zone. Taking workpiece identification applications as an example, the system must ascertain precisely which tags are really inside the reading zone, in order to subject the workpieces attached to these tags to further processing. However, multi-path transmission may cause the system to mistakenly identify tags outside the reading zone, and correspondingly to execute an erroneous processing command on the workpiece which is about to arrive.

**[0004]** There may be similar problems in logistics applications:

(1) In luggage tracking applications at airports, the lack of control over the reading zone results in difficulty in distinguishing between tagged luggage bags when they pass the antenna. To solve this problem, an expensive box made from material which absorbs radio waves must be used to control the reading zone.

(2) In forklift applications with multiple inlets, signal leakage leads to the reader cross-reading tags of inlets which are not the object of interest. As a result, it is very difficult to correctly identify movement of goods through different inlets.

(3) There is a similar impact in applications where the load of a goods forklift is to be accurately identified. The multipath problem results in a forklift equipped with an RFID system being unable to effectively distinguish between a background tag and a tag on the forklift pallet.

**[0005]** It can be seen that all of the application scenarios mentioned above require a controlled reading zone: within the required reading zone, tags can be read reliably and there are no field nulls; outside the reading zone, cross reading will not occur. It must be pointed out that control over reading zones in UHF RFID is an excellent research subject both from an industrial and an academic perspective. Existing solutions can be divided into two types: the first provides a controlled reading zone by improving and utilizing current RFID communication methods, while the second uses auxiliary measures to enhance current RFID systems.

I. The first type of solution concentrates on the following two aspects:

1. Using a far-field antenna to filter remote tags, and thereby controlling the reading zone

(1) OMRON proposes some solutions in US20070241904A1 and US20080198903A1, according to which the tag distance is measured by detecting phase difference in reflected carriers so as to perform distance filtering.

To overcome the multi-path problem, US20070241904A1 uses different frequencies to communicate with tags at different times, and records the phase shift of backscattered carriers on each frequency, so as to measure tag distance on each frequency. However, this solution is unable to detect a phase difference of 360 degrees when a tag moves a distance of half a wavelength.

In US20080198903A1, a solution for locating a tag on the basis of phase differences in two carriers of different frequencies is proposed. Ambiguity of distance measurement will not occur in this solution, but it can only analyze static phase differences on the two frequencies, and so can only obtain one fixed distance of a tag. Moreover, it is likely to be affected by the surrounding environment; for example, the phase differences will be affected by all reflective objects. If there is a metal plate very close to the tag, it will be impossible to distinguish between a reflection from the tag and a reflection from the metal plate by analyzing the phase differences. To solve this problem, the pattern in which phase difference varies with time must be analyzed. However, since there is an ambiguity of 360 degrees in a conventional IQ structure on each frequency, this solution is unable to obtain the above pattern.

(2) Intermec proposes a solution in which phase change in a conventional IQ structure is detected when a single carrier is used, and also proposes three phase difference of arrival (PDOA) methods in the time domain, frequency domain and spatial domain.

(3) Pavel et al. propose a solution capable of accurately locating a tag on the basis of the phase difference between two or more receiving antennas.
Since only a single carrier is used each time in solutions (2) and (3), these solutions have a similar flaw to that of solutions (1) (proposed by OMRON).

(4) In CN0160421A, AutoID Fudan proposes a solution based on direct sequence spread spectrum (DSSS) technology. In this solution, the backscattered signal from the tag is spread using DSSS technology. The reader then subjects the signal reflected from the tag to distance measurement based on the time difference (TOF, time of flight), using fast correlation. It must be pointed out that the reliability and accuracy of this solution are dependent on the speed of the PN code to a large degree. However, owing to the spreading operation, the use of a high-speed PN code will introduce a need for greater bandwidth, which cannot be supported by many existing RFID communication specifications.

(5) Different solutions have been proposed by Alien and Impinj, in which the reading zone is controlled indirectly by measuring the direction and speed of movement of the tag. However, this solution is only effective in scenarios involving moving tags. A new solution is required for scenarios involving stationary tags, i.e. this solution is not suitable for use with both stationary tags and moving tags.

2. Using a near-field (NF) antenna to control the reading zone
Another feasible solution to the problem of control over reading zones is a near-field UHF antenna. In this solution, a magnetic coupling scheme replaces radio wave transmission. Furthermore, the far-field gain of the antenna can be designed to be very small (e.g. -20 dBi). Thus it can be used to construct a controlled reading zone (see US20080048867A1). However, wavelengths are very small (about 30 cm) in the UHF band, and it is difficult to design an NF antenna with a large reading distance. Moreover, the far-field gain is proportional to the NF reading distance. Most NF antennas have a reading distance of about 5 cm; the maximum distance of a commercially available NF antenna is just 15 cm, and the far-field gain thereof can be as high as 6 dBi. Therefore it is very difficult to design an NF antenna with a long NF distance and a small far-field gain.

II. The main feature of the second type of solution is the introduction of auxiliary measures, and the attempt to obtain a controlled reading zone using these auxiliary measures.

(1) A solution proposed by Fujitsu involves using an infrared sensor on an antenna support to detect when a tag enters or leaves the reading zone, and setting a time for antenna switching based on the above information, so as to improve the efficiency of reading/writing large amounts of data relating to multiple moving tags.

(2) Different solutions have been proposed by Sverre Holm et al. and Mary Catherine et al. for integrating ultrasound into an RFID system. In these solutions, ultrasound may be used independently to obtain distance information for further processing, or a tag may be located on the basis of the difference in ultrasound and RF transmission times.

(3) There is another solution in the prior art which uses a material which absorbs radio waves to restrict transmission of radio waves. For instance, in airport luggage processing applications, a box made from an expensive material which absorbs radio waves is used to cover the required reading zone, and only tags which pass through the box will be read.

**[0006]** All these solutions require the use of new measures to obtain a controlled reading zone, increasing the cost of the entire system considerably. In some cases, the new measure (such as the box for absorbing radio waves) has a higher cost than the RFID system.

## Content of the invention

**[0007]** In view of the above, the present invention proposes a method for locating a tag using a radio frequency identification reader, and a radio frequency identification reader, by which a tag may be located more effectively.

**[0008]** To achieve the above object, the technical solution of the present invention is realized specifically as follows:

A method for locating a tag using a radio frequency identification (RFID) reader, comprising:

A. the reader transmitting a signal to the tag on at least two frequencies and receiving a corresponding reflected signal;

B. subjecting the reflected signal received to a combining operation to obtain a combined received signal, and mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag.

**[0009]** The at least two frequencies comprise: a first frequency f1 and a second frequency f2; and the step of receiving a corresponding reflected signal in step A comprises:
the reader obtaining a first received signal on the first frequency f1 at a first time, and obtaining a second received signal on the second frequency f2 at a second time, wherein the first time and the second time are different.

**[0010]** The step of subjecting the reflected signal received to a combining operation to obtain a combined received signal in step B comprises:

B1. obtaining a first in-phase component I1 and a first quadrature component Q1 from the first received signal, to construct a first signal vector V1 = I1 + jQ1;

B2. obtaining a second in-phase component 12 and a second quadrature component Q2 from the second received signal, to construct a second signal vector V2 = Q2 + jI2;

B3. adding the first signal vector V1 and the second signal vector V2 together, to obtain a combined received signal vector V.

**[0011]** The at least two frequencies comprise: a first frequency f1 and a second frequency f2; and the step in which the reader transmits a signal to the tag on at least two frequencies in step A comprises:

the reader generating a first transmission signal Acos(2πf1*t) on the first frequency f1, generating a second transmission signal Bcos(2πf2*t) on the second frequency f2, and sending a combined transmission signal Acos(2πf1*t)+Bcos(2πtf2*t) to the tag;

the step of subjecting the reflected signal received to a combining operation to obtain a combined received signal in step B comprises:

the reader mixing the reflected signal received with an I path local oscillator signal $$I_{LO}=\frac{\cos(2\pi f1*t)}{H1}+\frac{\sin(2\pi f2*t)}{H2},$$ to obtain a combined in-phase component $I_{new}$;

mixing the reflected signal received with a Q path local oscillator signal $$Q_{LO}=\frac{\sin(2\pi f1*t)}{H1}+\frac{\cos(2\pi f2*t)}{H2},$$ to obtain a combined quadrature component $Q_{new}$;

obtaining the combined received signal on the basis of the combined in-phase component $I_{new}$ and the combined quadrature component $Q_{new}$;

wherein the H1 is a first signal attenuation on the first frequency f1, and the H2 is a second signal attenuation on the second frequency f2.

**[0012]** Before step A, the method further comprises: C. setting the first frequency f1 and the second frequency f2, which are different from one another;
after step B, the method further comprises: D. after incrementing the number of tag locating operations performed by 1, determining whether it has reached a preset threshold; if it has, then terminating the process, otherwise changing the first frequency f1 and/or the second frequency f2 to increase the frequency difference therebetween, and returning to step A; or
after step B, the method further comprises: E. comparing the current tag location result with a historical tag location result, and if the difference therebetween is less than a preset threshold, then terminating the process, otherwise changing the first frequency f1 and/or the second frequency f2 to increase the frequency difference therebetween, and returning to step A.
**[0013]** The step of mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag in step B comprises: determining the tag distance d between the tag and the reader on the basis of a correlation between tag distance d and constellation point vector angle θ.
**[0014]** The correlation between tag distance d and constellation point vector angle θ is: the vector angle θ of the constellation point is directly proportional to $\frac{2d}{c}(f2\text{-}f1)$, wherein c is the speed of light.

**[0015]** The step of mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag in step B comprises:

determining a first constellation point locus when the tag is in a first state on the basis of the combined received signal, and finding a first boundary position and a second boundary position of the first constellation point locus on the constellation diagram;

determining a second constellation point locus when the tag is in a second state on the basis of the combined received signal,

and finding the position of an external reflective object from the first boundary position and the second boundary position on the basis of the second constellation point locus, so as to determine the tag position on the constellation diagram; wherein the external reflective object is another reflective object besides the tag, and the tag has different reflective properties in the first state and the second state;

determining the corresponding tag distance d on the basis of the vector angle θ of the tag position on the constellation diagram.

**[0016]** The method further comprises: the reader compares the tag distance d of one or more tags with a preset threshold, and reports information about any tag for which the tag distance d is in conformity with the preset threshold to a control center.
**[0017]** The step of mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag in step B comprises:

measuring the tag distance d of the tag at different positions on the first frequency f1 and the second frequency f2;

determining the speed of movement of the tag on the basis of the distance between the positions and the time of movement of the tag;

estimating the path of movement of the tag on the basis of different detected positions and the speed of movement.

**[0018]** The method further comprises: arranging multiple readers to point in different directions, determining the tag distance d between the tag and each reader, and obtaining coordinates of the tag in three dimensions on the basis of the multiple tag distances d.
**[0019]** Before step A, the method further comprises: the reader measuring the average Received Signal Strength Indication (RSSI) value, and filtering out tags for which the actual RSSI value is less than the average RSSI value.
**[0020]** A radio frequency identification (RFID) reader, comprising:

a control unit, for directing a frequency generation unit to generate at least two frequencies;

a signal transmission unit, for transmitting a signal to a tag on the at least two frequencies generated;

the control unit being further used for: subjecting a reflected signal received by a signal receiving unit to a combining operation to obtain a combined received signal, and mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag.

**[0021]** The at least two frequencies comprise: a first frequency f1 and a second frequency f2;
the signal receiving unit is used for obtaining a first received signal from the tag on the first frequency f1 at a first time, and for obtaining a second received signal from the tag on the second frequency f2 at a second time, wherein the first time and the second time are different;
the control unit is used for combining the first received signal with the second received signal, to obtain the combined received signal.
**[0022]** The control unit is further used for:

obtaining a first in-phase component I1 and a first quadrature component Q1 from the first received signal, and constructing a first signal vector V1 = I1 + jQ1;

obtaining a second in-phase component 12 and a second quadrature component Q2 from the second received signal, and constructing a second signal vector V2 = Q2 + jI2;

adding the first signal vector V1 and the second signal vector V2 together, to obtain a combined received signal vector V.

**[0023]** The at least two frequencies comprise: a first frequency f1 and a second frequency f2;
the signal transmission unit is used for generating a first transmission signal Acos(2πf1*t) on the first frequency f1, generating a second transmission signal Bcos(2πf2*t) on the second frequency f2, and emitting a combined transmission signal Acos(2πf1*t)+Bcos(2πf2*t).
**[0024]** The signal receiving unit comprises a first receiving module and a second receiving module;
the first receiving module is used for mixing a signal obtained by a receiving antenna with an I path local oscillator signal

$$I_{LO} = \frac{\cos(2\pi f1 * t)}{H1} + \frac{\sin(2\pi f2 * t)}{H2},$$

to obtain a combined in-phase component $I_{new}$, and supplies this to the control unit;
the second receiving module is used for mixing a signal obtained by the receiving antenna with a Q path local oscillator signal $Q_{LO} = \frac{\sin(2\pi f1 * t)}{H1} + \frac{\cos(2\pi f2 * t)}{H2}$, to obtain a combined quadrature component $Q_{new}$, and supplies this to the control unit;
the control unit is used to obtain the combined received signal on the basis of the combined in-phase component $I_{new}$ and the combined quadrature component $Q_{new}$;
wherein the H1 is a first signal attenuation on the first frequency f1, and the H2 is a second signal attenuation on the second frequency f2.
**[0025]** The reader further comprises: a signal attenuation unit;
the control unit being used for directing the signal transmission unit to transmit a signal on the first frequency f1 to obtain H1 by channel estimation, and directing the signal attenuation unit to generate a first attenuation factor G1 = 1/H1 for the first frequency f1, and for directing the signal transmission unit to transmit a signal on the second frequency f2 to obtain H2 by channel estimation, and directing the signal attenuation unit to generate a second attenuation factor G2 = 1/H2 for the second frequency f2.
**[0026]** The control unit is further used for:
directing the frequency generation unit to change the first frequency f1 and/or the second frequency f2, to increase the frequency difference therebetween, and directing the signal transmission unit to transmit a signal to the tag on the first frequency f1 and second frequency f2 after the change.
**[0027]** The control unit is further used for: determining the tag distance d between the tag and the reader on the basis of a correspondence between tag distance d and constellation point vector angle θ.

**[0028]** The control unit is used for:

determining a first constellation point locus when the tag is in a first state on the basis of the combined received signal, and finding a first boundary position and a second boundary position of the first constellation point locus on the constellation diagram;

determining a second constellation point locus when the tag is in a second state on the basis of the combined received signal, and finding the position of an external reflective object from the first boundary position and the second boundary position on the basis of the second constellation point locus, so as to determine the tag position on the constellation diagram; wherein the external reflective object is another reflective object besides the tag, and the tag has different reflective properties in the first state and the second state;

determining the corresponding tag distance d on the basis of the vector angle $\theta$ of the tag position on the constellation diagram.

**[0029]** The tag locating method and RFID reader provided in the embodiments of the present invention transmit a signal to a tag on at least two frequencies, and map a combined received signal onto a constellation diagram, increasing the accuracy of the tag distance determined.

**Description of the accompanying drawings**

**[0030]**

Fig. 1 shows the scenario in one embodiment of the present invention in which a signal emitted from a reader is transmitted along three paths;

Fig. 2 is a simulated schematic diagram of a field null when three different schemes are used;

Fig. 3 is a flow chart of the method by which an RFID reader locates a tag in one embodiment of the present invention;

Fig. 4 is the IQ structure obtained using two carriers in one embodiment of the present invention;

Fig. 5(a) shows the IQ structure when distance d = 0;

Fig. 5(b) shows the IQ structure when distance d = 0.5 m;

Fig. 5(c) shows the IQ structure when distance d = 1.5 m;

Fig. 6(a) is the IQ mapping when f1 = 865.7 MHz and f2 = 867.5 MHz;

Fig. 6(b) is the IQ mapping when f1 = 865.7 MHz and f2 = 916.2 MHz;

Fig. 7 is a flow chart of a method for performing two-stage distance filtering using different frequency combinations in one embodiment of the present invention;

Fig. 8 is a schematic diagram of reflection states of metal and tag during communication;

Fig. 9 shows the loci of constellation points in the IQ structure for two different states;

Fig. 10 shows constellation diagrams captured during simulation for four different states;

Fig. 11 is a schematic diagram of the TX/RX chain of a reader in one embodiment of the present invention;

Fig. 12 is a schematic diagram of the structure of a dual-carrier reader in another embodiment of the present invention;

Fig. 13 shows the channel estimation process for a reader in one embodiment of the present invention.

**Particular embodiments**

**[0031]** The present invention is described in further detail below by way of examples with reference to the accompanying drawings, in order to clarify the object, technical solution and advantages thereof.

**[0032]** The present invention proposes a solution based on at least two carriers. On the one hand, at least two carriers on different frequencies are used to activate a tag, so as to eliminate field nulls in a required zone; on the other hand, reflected signals on at least two carriers are combined and then mapped to a constellation point on a constellation diagram, to construct a special IQ structure. In this structure, each point uniquely represents one tag distance in the reading zone. Thus by finding the locus of the constellation point in the IQ structure (also called a constellation diagram), and using a particular pattern recognition method to analyze this locus, it is possible to identify a reflection from the tag and determine the tag distance. According to the method of the present invention, tags outside the required zone will be filtered out, so that a controlled reading zone can be achieved even in a complex environment.

**[0033]** Specifically, the present invention proposes a method for locating a tag using a radio frequency identification (RFID) reader, comprising: A. the reader transmitting a signal to the tag on at least two frequencies and receiving a corresponding reflected signal; B. subjecting the reflected signal received to a combining operation to obtain a combined received signal, and mapping the combined received signal to a constellation point on a constellation diagram, for the purpose of locating the tag.

**[0034]** The method proposed in the present invention uses at least two carriers to activate the tag, unlike conventional reader designs having only a single carrier. This is illustrated below using the example of two frequencies (a first frequency f1 and a second frequency f2); the situation is similar when more than two frequencies are used. In multi-path transmission scenarios, frequency diversity will occur in the RF signal on the two carriers, so that field nulls in the reading zone are eliminated. The improvement brought about by the present invention with respect to field nulls is demonstrated below by means of a simulation; as Fig. 1 shows, this simulation constructs a three-path transmission scenario. Specifically, one path is from the reader 101 to the tag 102, another path is from the reader 101 to a metal reflector 103, and another path is from the reader 101 to a metal base 104. The distance d between the reader 101 and the tag 102 (also called the tag distance) is approximately 2 - 3 m, while the distance d2 between the reader 101 and the metal reflector 103 is 3.1 m.

**[0035]** Fig. 2 uses three different schemes to simulate the relative path loss in the three-path transmission scenario shown in Fig. 1, so as to compare the field nulls of these three schemes. In scheme 1, only a single carrier is used; in scheme 2, two carriers are used with frequency hopping; in scheme 3, two carriers (865.7 MHz and 916.2 MHz) are used simultaneously. It can be seen from the simulation result that a field null represented by a relative path loss of -40 dB occurs in the single-carrier scheme, whereas schemes 2 and 3 can both eliminate this field null. Evidently, the field null problem can be ameliorated more effectively when a two-carrier scheme is used. It must be pointed out that the greater the difference in frequency between the two carriers, the better the frequency diversity result. Since the ETSI standard (e.g. ETSI TR 102 649-2 V 1.1.1) will allow a new channel scheme to be set at 915 MHz, the two channels may be selected as f1 = 865.7 MHz and f2 = 916.2 MHz in European applications.

**[0036]** Fig. 3 is a flow chart of the method by which an RFID reader locates a tag in one embodiment of the present invention, comprising the following steps:

Step 301: the reader transmits a signal to a tag on at least two frequencies and receives a corresponding reflected signal.

**[0037]** It must be pointed out that reflected signals from different tags are received at different times (e.g. time slots), and can be distinguished from one another by means of tag IDs. Further, in the case of more complex external environments, not only the signal reflected by the tag but also signals reflected from external reflective objects (i.e. other reflective objects besides the tag) will be received at a particular time.

**[0038]** Step 302: the reflected signal received is subjected to a combining operation to obtain a combined received signal, which is then mapped onto a constellation diagram.

**[0039]** As mentioned above, movement of the tag by a distance of half a wavelength will lead to a phase change of 360 degrees, and this cannot be detected in a conventional IQ structure. In a conventional IQ structure, the in-phase component $I = \cos(2\pi f t_0)$ and the quadrature component $Q = \sin(2\pi f t_0)$. In order to overcome the abovementioned uncertainty of distance, the present invention proposes a new IQ mapping scheme in which at least two carriers are combined.

**[0040]** Taking the example of two carriers, in the present invention, $I' = \cos(2\pi f1 * t_0) + \sin(2\pi f2 * t_0)$ and $Q' - \sin(2\pi f1 * t_0) + \cos(2\pi f2 * t_0)$. Therefore in the special IQ structure of the present invention, the combined in-phase component $I_{new} = \frac{I'}{\sqrt{(I')^2 + (Q')^2}}$, and the combined quadrature component $Q_{new} = \frac{Q'}{\sqrt{(I')^2 + (Q')^2}}$. Specifically, Fig. 4 shows the vector sum of two carriers (continuous wave, CW) in the special IQ structure. As Fig. 4 shows, the new IQ mapping may be interpreted as the sum of two vectors on two carriers. In the IQ structure defined as in the present invention, each constellation point (dependent on f2 - f1) uniquely represents a tag distance in a particular zone. Figs. 5(a) - (c) are three examples of distance mapping in the special IQ structure, wherein f1 and f2 are selected as 865.7 MHz and 916.2 MHz, respectively. Specifically, Fig. 5(a) shows the case where distance d = 0, Fig. 5(b) shows the case where distance d = 0.5 m, and Fig. 5(c) shows the case where distance d = 1.5 m.

**[0041]** In one particular implementation, the reader transmits a signal to a tag at different times on a first frequency f1 and a second frequency f2, respectively. Correspondingly, the reader receives a first received signal from the tag on the first frequency f1, and obtains a second received signal from the tag on the second frequency f2.

**[0042]** The difference in frequency between the second frequency f2 and first frequency f1 is $\Delta f$, and a first signal vector V1 = I1 + jQ1 is combined with a second signal vector V2 = Q2 + jI2 by the method shown in Fig. 4 to form a received signal vector $V = I_{new} + jQ_{new}$, to improve the result of uniquely representing the tag distance according to the vector angle.

**[0043]** In another particular implementation, the reader transmits a signal to a tag on a first frequency f1 and a second frequency f2 at the same time, i.e. the reader emits a combined transmission signal $A\cos(2\pi f1{*}t)+B\cos(2\pi f2{*}t)$. Correspondingly, the reader mixes a reflected signal received with an I path local oscillator signal $I_{LO}=\frac{\cos(2\pi f1{*}t)}{H1}+\frac{\sin(2\pi f2{*}t)}{H2}$ to obtain a combined in-phase component $I_{new}$, mixes the reflected signal received with a Q path local oscillator signal $Q_{LO}=\frac{\sin(2\pi f1{*}t)}{H1}+\frac{\cos(2\pi f2{*}t)}{H2}$ to obtain a combined quadrature component $Q_{new}$, and then combines the combined in-phase component $I_{new}$ with the combined quadrature component $Q_{new}$ to form a received signal vector $V = I_{new} + jQ_{new}$.

**[0044]** It must be pointed out that in step 302 above, the manner in which a reflected signal received is combined may involve: determining an in-phase component $I = \cos(2\pi f t_0)$ and a quadrature component $Q = \sin(2\pi f t_0)$ on each frequency, combining the four components I1, I2, Q1 and Q2 on the two frequencies in an arbitrary manner to obtain a first signal vector V1 and a second signal vector V2, and then adding these two signal vectors together to obtain a received signal vector V. For example, in one particular implementation, the first signal vector V1 = I1 + jI2 while the second signal vector V2 = Q1 + jQ2. Alternatively, the four components I1, I2, Q1 and Q2 on the two frequencies are combined in an arbitrary manner to obtain an I path local oscillator signal and a Q path local oscillator signal. For example, in another particular implementation, $I_{LO}=\frac{\cos(2\pi f1{*}t)}{H1}+\frac{\cos(2\pi f2{*}t)}{H2}$ and $Q_{LO}=\frac{\sin(2\pi f1{*}t)}{H1}+\frac{\sin(2\pi f2{*}t)}{H2}$.

**[0045]** Of course, in the case of three or more carriers, the method of combining two carriers may be extended, for instance by combining a signal vector Vi on the $i^{th}$ carrier with a signal vector Vj on the $j^{th}$ carrier (e.g. by the method shown in Fig. 4) to obtain a signal vector Vm, then combining Vm with a signal vector Vk on the $k^{th}$ carrier, and so on until the signal vectors on all the carriers have been included in the combining operation, so as to obtain a final received signal vector V. Alternatively, the signal vector Vk on the $k^{th}$ carrier is combined with a signal vector Vp on a $p^{th}$ carrier to obtain a signal vector Vn, which is then combined with Vm.

**[0046]** Step 303: the tag is located on the basis of the position of the constellation point of the received signal vector V on the constellation diagram; for instance, a corresponding tag distance d is determined.

**[0047]** Specifically, once the received signal vector V has been drawn on the constellation diagram, the tag distance d is determined on the basis of the vector angle $\theta$ (see Fig. 4), each vector angle corresponding to one tag distance. It must be pointed out that the accuracy of the correspondence between vector angle and tag distance is dependent upon the difference in frequency between f2 and f1. With a smaller $\Delta f$, the reader can determine tags within a larger range of distances, but with a larger error; with a larger $\Delta f$, the reader can only determine tags within a smaller range of distances, with a correspondingly smaller error.

**[0048]** In one particular implementation, the tag distance d is determined according to the formula

$$\theta=\begin{cases}\frac{\pi}{4}+\pi\frac{2d}{c}(f2\text{-}f1),Q'>0\\ \frac{5\pi}{4}+\pi\frac{2d}{c}(f2\text{-}f1),Q'<0\end{cases}$$

$\theta$ is the vector angle, d is the tag distance, c is the speed of light and

$Q' = \sin(2\pi f1 * t_0) + \cos(2\pi f2 * t_0)$. In general, the vector angle $\theta$ is directly proportional to $\frac{2d}{c}(f2-f1)$, so that the mapping of the combined received signal on the constellation diagram can uniquely represent tag distance over a larger range.

**[0049]** Steps 304 - 305 are further performed: judging whether there is a need to determine tag distance d again, and if so, changing f1 and/or f2 so that the difference in frequency therebetween changes (e.g. $\Delta f$ increases) and repeating steps 301 - 303, so as to estimate tag distance with greater accuracy.

**[0050]** It must be pointed out that the capacity for distance filtering of the special structure IQ provided in the present invention is dependent to a large degree on the difference in frequency f2 - f1 between the two carriers. With a smaller frequency difference between the two carriers, the uniquely represented range of distances which can be obtained is larger. However, it is more difficult to distinguish between distances with a higher level of precision. On the other hand, with a larger frequency difference between the two carriers, the range of distances which can be uniquely represented is smaller, but distances can be distinguished from one another with a high level of precision.

**[0051]** Specifically, Figs. 6(a) and 6(b) show two examples of the IQ structure defined in the present invention. Fig. 6(a) is an IQ mapping when f1 = 865.7 MHz and f2 = 867.5 MHz; Fig. 6(b) is an IQ mapping when f1 = 865.7 MHz and f2 = 916.2 MHz. It can be seen that in Fig. 6(a) the frequency difference is smaller, and the range of distances which the IQ structure can map is 0 - 15 m, wherein 611 and 612 are 0 - 2.9 m while 613 and 614 are 2.9 m - 15 m. However, the accuracy of distance mapping is not high, and the error arising from the fact that the constellation points have relatively small vector angles will result in a large divergence between the determined tag distance and the actual situation. In Fig. 6(b) the frequency difference is larger, and the range of distances which the IQ structure can map is 0 - 2.9 m, wherein 621 and 622 are 0 - 1 m while 623 and 624 are 1 m - 2.9 m, but the accuracy of distance mapping is higher.

**[0052]** Based on the situation described above, Fig. 7 shows the procedure of a method for performing N-stage distance filtering using different frequency combinations in one embodiment of the present invention, wherein N is any positive integer. In general, N is 2, i.e. two different frequency combinations are used for tag filtering, such that the tag is filtered in two different ways, that is to say, coarsely and finely, so as to increase the accuracy of filtering. Of course, the use of two carriers with a relatively small frequency difference to determine tag distance is not the only way of performing coarse filtering; another way is to measure the average Received Signal Strength Indication (RSSI) value, and to filter out remote tags for which the RSSI value is too small.

**[0053]** Of course, in step 304 above, the reader can repeat steps 301 - 303 N times (where N is any positive integer) according to a predetermined setting, so as to obtain the required tag distance. For example, after incrementing the number of tag locating operations performed by 1, the reader determines whether it has reached a preset number of times. If it has, the process is terminated or step 306 is performed; otherwise, the first frequency f1 and/or the second frequency f2 is/are changed to increase the difference in frequency therebetween, and the process returns to step 301. Alternatively, the reader compares the current tag location result with a historical tag location result (e.g. the previous tag location result or any previous tag location result), and if the difference therebetween is less than a preset threshold, then the process is terminated or step 306 is performed. For example, the reader can compare a preset difference value with the difference between the tag distance determined this time and the tag distance determined the previous time, so as to determine whether it is necessary to determine the tag distance d again. With regard to step 305, the reader may also decide how to change f2 and/or f1 according to a predetermined setting; this shall not be elaborated superfluously here.

**[0054]** Step 306 is further performed: the reader performs filtering on the basis of the determined tag distance, and reports information about some or all tags located within a preset distance to a control center or host computer, at which point the process ends.

**[0055]** Specifically, the preset distance may be a range of distances, i.e. the reader reports information about tags located within this range of distances. Alternatively, the preset distance may be a single value, and the reader correspondingly reports information about tags for which the tag distance is less than the preset distance. Using the method of step 306 enables the reader to filter the tags on the basis of tag distance, so it can avoid providing tags which have been cross-read to the control center; this makes the reporting of information to the control center by the reader more accurate.

**[0056]** In the process shown in Fig. 3, based on the special IQ structure, the present invention can further distinguish between reflections from tags and from the external environment and determine tag distance during the communication process by analyzing the loci of constellation points in the IQ structure. It must be pointed out that a tag has two reflection states, unlike fixed reflections from the external environment, and the loci of the constellation points of these two states in the IQ structure will also be somewhat different.

**[0057]** In one application scenario of the present invention, a metal plate (as an example of the external environment) is placed in front of the reader antenna. The metal plate always reflects signals completely, whereas the tag has two different reflective properties; for instance, the first state is complete signal reflection (which could be chip impedance open circuit or short circuit), while the second state is partial signal reflection (which could be matching of the chip impedance to the tag antenna, etc.). Fig. 8 is a schematic diagram of reflection states of metal and tag in this application scenario. Specifically, before a backscatter FM0/Miller code is emitted, the tag completely reflects the signal (i.e. state 1); when the backscatter FM0/Miller code is emitted (e.g. the EPC stage in Fig. 13), the tag will reflect LOW and HIGH alternately in the code, wherein partial reflection is manifested as LOW in the code (i.e. state 2) and complete reflection is manifested as HIGH in the code.

**[0058]** Fig. 9 shows the loci of constellation points in the IQ structure for two different states. In state 1, both metal and tag reflect completely, so the constellation point in the IQ structure moves between the position of the metal and the position of the tag, the loci thereof being within the range indicated by the dotted line in Fig. 9. In state 2, the tag only partially reflects, so the locus of the constellation point will be closer to the position of the metal (the range thereof being indicated by the solid line in Fig. 9), and the position of the tag cannot be reached. Thus by first determining two boundary points of the locus in state 1 and then determining the position of the metal according to the locus in state 2, the position of the tag in the constellation diagram can be found. In addition, certain pattern recognition methods such as point clustering may also be used to distinguish between the position of the metal and the position of the tag in the IQ structure; on this basis, reflections from the tag can then be identified, and tag distance measured. It must be pointed out that the position of the metal and the position of the tag are each one constellation point on the constellation diagram. Of course, the above process can be carried out on the reader, and the tag information can be reported to the control center by the reader, the control center then finding the position of the tag on the constellation diagram on the basis of the tag information.

**[0059]** The method provided in the present invention is verified by way of simulation below. In this simulation, a tag is placed at a position 0.33 m from the reader antenna, and a metal plate is placed at a position 0.8 m from the reader antenna. Fig. 10 shows constellation diagrams captured during simulation for four different states. Fig. 10(a) shows a constellation point (0, 0) when there is no signal reflection. Fig. 10(b) shows a constellation point (0.93, 0.43) when there is only reflection from the tag located at d = 0.33 m. Fig. 10(c) shows a constellation point when there is simultaneous reflection from both the tag and the metal. It must be pointed out that this constellation point moves between the two constellation points corresponding to tag reflection only and metal reflection only; Fig. 10(c) is merely the position thereof at a particular instant. Fig. 10(d) shows a constellation point (-1.39, 0.08) when there is only reflection from the metal located at d = 0.8 m. It can be seen from the results of simulation shown in Fig. 10 that when only the tag reflects the signal, the constellation point remains at the position of the tag. When only the metal reflects the signal, the constellation point moves to the position of the metal. When the tag and the metal simultaneously reflect the signal, the constellation point lies between the above two positions, the pattern in which it moves being dependent upon the tag reflection state. Using certain pattern recognition methods, reflection from the tag can be identified, as can the corresponding tag distance.

**[0060]** Using the tag location method provided in the present invention, it is further possible to track tagged moving targets in a reflective environment (e.g. a production environment). Specifically, the path of movement of the tag is estimated as follows:

1. Positions of the tag where there is no field null on either of two frequencies are detected, and the tag distances for each position recorded.

2. The speed of movement of the tag is estimated on the basis of the distance between the above positions and the time taken for the tag to move between the above positions.

3. Based on the speed of movement and previously detected positions where there is no field null (also called historical detection positions), interpolation or another method is used to estimate positions through which the tag has passed and which are located in a field null (e.g. positions which cannot be covered by the reader), to obtain the path of movement of the tag.

**[0061]** Compared with the prior art, the method provided in the present invention transmits a signal to a tag on at least two carriers and correspondingly receives a reflected signal, combines the reflected signal received, and in turn locates the tag on the basis of the combined received signal. Specifically, the present invention measures tag distance on the basis of the combined received signal, uses the tag distance obtained to filter out remote tags, and thereby reduces the ambiguity of tag filtering. Further, the present invention uses the loci of combined received signals on a constellation diagram to distinguish between reflection from a tag and reflection from the surrounding environment (e.g. nearby metal), and will not be affected greatly by the surrounding environment. Further, the present invention may also have multiple readers arranged to point in different directions, determine the tag distance d between a particular tag and each reader by the process shown in Fig. 3, and obtain the coordinates in three dimensions of that tag on the basis of the multiple tag distances d, so as to more accurately ascertain the location of the tag.

**[0062]** Further, the present invention provides multiple radio frequency identification (RFID) readers suitable for use with the above tag locating method, comprising: a control unit, for directing a frequency generation unit to generate at least two frequencies; and a signal transmission unit, for transmitting a signal to the tag on the at least two frequencies generated. The control unit is further used for: subjecting a reflected signal received by a signal receiving unit to a combining operation to obtain a combined received signal, and mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag.

Embodiment 1:

**[0063]** Fig. 11 is a schematic diagram of the TX/RX chain of a reader in one embodiment of the present invention. In this embodiment, the software and/or hardware of an ordinary reader is modified and upgraded in a simple manner, enabling it to measure tag distance, and in turn to filter tags or determine the path of movement of a tag on the basis of the tag distance d obtained. Specifically, the reader comprises at least one of the following units: a control unit 1101, a frequency generation unit 1102, a signal receiving unit 1103 and a signal transmission unit 1104.

**[0064]** In the signal receiving unit 1103, a signal obtained by a receiving (RX) antenna through communication with a particular tag is split into two lines. One line is mixed with a signal $\cos(2\pi ft)$ generated by the frequency generation unit 1102 before being processed in a low-pass filter (LPF) and an analog-to-digital conversion (ADC) module, and then supplied to the control unit 1101 by a first receiving digital signal processing (DSP RX) module. Another line is mixed with a signal $\sin(2\pi ft)$ obtained by subjecting a signal generated by the frequency generation unit 1102 to phase-shift processing, processed in an LPF and ADC module, and then supplied to the control unit 1101 by a second DSP RX module. Here, H reflects signal attenuation and circuit effects.

**[0065]** Specifically, the signal receiving unit 1103 obtains a first received signal $AH\cos(2\pi f1*(t-t_0))$ on the first frequency f1 at a first time, obtains a first in-phase component $I1=AH\cos(2\pi f1*t_0)$ and a first quadrature component $Q1=AH\sin(2\pi f1*t_0)$ from the first received signal, and supplies these to the control unit 1101. The signal receiving unit 1103 obtains a second received signal $AH\cos(2\pi f2*(t-t_0))$ on the second frequency f2 at a second time, obtains a second in-phase component $I2=AH\cos(2\pi f2*t_0)$ and a second quadrature component $Q2=AH\sin(2\pi f2*t_0)$) from the second received signal, and supplies these to the control unit 1101. The first time and the second time are different.

**[0066]** In the signal transmission unit 1104, a transmitting digital signal processing (DSP TX) module sends a signal to a digital-to-analog conversion (DAC) module for processing; after passing through a mixer and an amplifier, the signal is output to the transmitting (TX) antenna.

**[0067]** The control unit 1101 is used for directing the frequency generation unit 1102 to generate the first frequency f1 and second frequency f2 at different times, for the purpose of transmitting signals to the tag. In one particular implementation of the present invention, the frequency generation unit 1102 is an oscillator.

**[0068]** Further, the control unit 1101 is used for receiving a first in-phase component I1' supplied by the first DSP RX module and a first quadrature component Q1' supplied by the second DSP RX module, normalizing the I, Q values (i.e. I1' and Q1') received on the first frequency f1 to obtain I1 and Q1, and storing these as a first signal vector V1 = I1 + jQ1. It must be pointed out that the normalization operation is by no means essential; the signal received by the control unit 1101 may be a normalized first in-phase component I1 and normalized first quadrature component Q1. In other words, the first in-phase component may be pre-normalization I1' or post-normalization I1, or I1' may be equal to I1. Of course, processing of the first quadrature component is similar to that of the first in-phase component, and shall not be elaborated superfluously here.

$$I1=\frac{I1'}{\sqrt{(I1')^2+(Q1')^2}}=\cos(2\pi f1*t_0)$$

$$Q1=\frac{Q1'}{\sqrt{(I1')^2+(Q1')^2}}=\sin(2\pi f1*t_0)$$

**[0069]** Further, the control unit 1101 is used for normalizing the I and Q values (i.e. 12' and Q2') received on the second frequency f2 to obtain I2 and Q2 in a manner similar to that used for the first frequency f1 after receiving a second in-phase component 12' supplied by the first DSP RX module and a second quadrature component Q2' supplied by the second DSP RX module, and storing 12 and Q2 as a second signal vector V2 = Q2 + jI2. Similarly, the second in-phase component may be pre-normalization 12' or post-normalization 12, or 12' may be equal to 12. The situation is similar for the second quadrature component.

$$I2=\frac{I2'}{\sqrt{(I2')^2+(Q2')^2}}=\cos(2\pi f2*t_0)$$

$$Q2=\frac{Q2'}{\sqrt{(I2')^2+(Q2')^2}}=\sin(2\pi f2*t_0)$$

**[0070]** Further, the control unit 1101 is used to add the first signal vector V1 and the second signal vector V2 together, to obtain a combined received signal vector V = I + jQ for the tag, i.e. the final values of I and Q are as follows:

$$I_{new}=\frac{I1+Q2}{\sqrt{(I1+Q2)^2+(I2+Q1)^2}}$$

$$Q_{new}=\frac{Q1+I2}{\sqrt{(I1+Q2)^2+(I2+Q1)^2}}$$

**[0071]** Further, the control unit 1101 is used for mapping the combined received signal vector V onto a constellation diagram, and thereby determining the distance between the reader and the tag (also called tag distance d) on the basis of the IQ structure.

**[0072]** It can be seen that two-step frequency hopping is applied in an ordinary reader to realize the reader in this embodiment; communication with the tag is carried out in two steps using different frequencies (f1 and f2), and the ordinary reader is subjected to comparatively minor modifications to enable it to measure tag distance. Moreover, the I and Q values are normalized on each frequency, so that there is no need for channel attenuation information when constructing the IQ structure. During a particular implementation, the control unit 1101 may be a hardware unit (e.g. an a newly added MCU), or a software module, and so is easily added to the ordinary reader.

**[0073]** It must be pointed out that the reader provided in this embodiment must change frequency before obtaining the tag distance, and 20 ms are required for phase-locked loop (PLL) locking when the frequency is changed. In most applications, the distance moved by a tag in this period of time will not be too large (e.g. just 4 cm when the speed of movement reaches 2 m/s), and so the accuracy of distance filtering will not be affected.

Embodiment 2:

**[0074]** If the application is in an environment in which tags move at high speed, the reader provided in another embodiment of the present invention may be used to transmit two carriers (CW) simultaneously. Fig. 12 is a schematic diagram of the structure of a dual-carrier reader in another embodiment of the present invention; new hardware units for transmitting two CWs simultaneously have been added to the reader. Similarly to Fig. 11, the reader in Fig. 12 comprises: a control unit (which may be an MCU, etc.) 1201, a frequency generation unit 1202, a signal receiving unit 1203 and a signal transmission unit 1204, and may further comprise: a signal attenuation unit 1205. The first DSP RX, second DSP RX, MCU, first DSP TX and second DSP TX form the digital processing part of the reader.

**[0075]** In the reader shown in Fig. 12, a first transmission signal Acos($2\pi$f1*t is generated on f1 and a second transmission signal Bcos($2\pi$f2*t) is generated on f2; these two signals are combined, and the transmission signal finally sent to the transmitting antenna is Acos($2\pi$f1*t)+Bcos($2\pi$f2*t). Since the channel attenuation and circuit impact of each channel are different, the backscattered signal received from a tag is: AH1*cos($2\pi$f1*(t-$t_0$))+BH2*cos($2\pi$f2*(t-$t_0$)). In one particular implementation, f1 = 865.7 MHz and f2 = 916.2 MHz. By combining the above two carriers, local oscillator (LO) signals on the I channel and Q channel can be obtained.

$$I_{LO}=\frac{\cos(2\pi f1*t)}{H1}+\frac{\sin(2\pi f2*t)}{H2}$$

$$Q_{LO}=\frac{\sin(2\pi f1*t)}{H1}+\frac{\cos(2\pi f2*t)}{H2}$$

**[0076]** Signals obtained by the receiving antenna are mixed with the LO signals by means of a mixer to obtain the following I and Q values:

$$I'=A\cos(2\pi f1*t_0)+B\sin(2\pi f2*t_0)$$

$$Q'=A\sin(2\pi f1*t_0)+B\cos(2\pi f2*t_0)$$

**[0077]** An IQ structure to be used for distance filtering may then be constructed from these I and Q values.

**[0078]** In the above process, H1 is the channel attenuation and circuit impact on the first frequency f1, while H2 is the channel attenuation and circuit impact on the second frequency f2. Specifically, to compensate for the attenuation of each channel, a training process (e.g. channel estimation) may be used to obtain H1 and H2; compensation for channel attenuation can then be provided for each carrier by means of automatic gain control (AGC). Fig. 13 shows the channel estimation process for a reader in one embodiment of the present invention. Specifically, the reader emits a query signal, and transmits a signal on the first frequency f1 in order to estimate the signal attenuation on f1 (including channel attenuation and circuit impact, etc.). The reader then emits an ACK signal, and transmits a signal on the second frequency f2 in order to estimate the signal attenuation on f2. The reader then emits another ACK signal, and transmits a signal on the first frequency f1 and the second frequency f2 simultaneously to measure tag distance. In other words, during communication between the reader and the tag, the reader first estimates signal attenuation on each carrier (f1 and f2) separately by communicating with the tag, and then emits a signal on f1 and f2 to measure tag distance. It must be pointed out that when the first channel attenuation H1 is being estimated, the MCU suppresses signal transmission on the second frequency f2 by controlling the second GC; similarly, when the second signal attenuation H2 is being estimated, the MCU suppresses signal transmission on the first frequency f1 by controlling the first GC.

**[0079]** Clearly, the tag locating method and reader provided in the embodiments of the present invention comprise at least one of the following solutions:

1. Using at least two carriers to reduce field nulls in an RFID system (e.g. a UHF passive RFID system, etc.), and mapping a combined received signal onto a constellation diagram, so as to locate tags with greater convenience and accuracy on the basis of constellation points. For example, the reader uses two carriers to activate a tag, and combines the two carriers to construct a special IQ structure. Each constellation point in this IQ structure can uniquely represent one tag distance in a particular zone when the $\Delta$f between the two carriers used is fixed.

2. Using distance filtering in N steps, where N is any positive integer. For instance, when using a two-stage filtering solution to accurately locate a tag, coarse filtering is first carried out on the basis of RSSI detection in order to filter out remote tags; fine filtering is then used to identify tags in the required zone. Of course, a combination of more frequencies may be used for distance filtering, to increase the range of distances which can be represented uniquely.

3. Correctly identifying reflections from tags in a complex environment by analyzing the loci of constellation points in the IQ structure, so as to determine the corresponding tag distances.

4. Tracking moving targets by continuous distance measurement and analysis of historical detection points.

## Claims

**1.** A method for locating a tag using a radio frequency identification (RFID) reader, comprising:

A. the reader transmitting a signal to the tag on at least two frequencies and receiving a corresponding reflected signal;
B. subjecting the reflected signal received to a combining operation to obtain a combined received signal, and mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag;

wherein the at least two frequencies comprise: a first frequency f1 and a second frequency f2; and the step of receiving a corresponding reflected signal in step A comprises:
the reader obtaining a first received signal on the first frequency f1 at a first time, and obtaining a second received signal on the second frequency f2 at a second time, wherein the first time and the second time are different; and wherein the step of subjecting the reflected signal received to a combining operation to obtain a combined received signal in step B comprises:

B1. obtaining a first in-phase component I1 and a first quadrature component Q1 from the first received signal, to construct a first signal vector V1 = I1 + jQ1;
B2. obtaining a second in-phase component 12 and a second quadrature component Q2 from the second received signal, to construct a second signal vector V2 = Q2 + jI2; **characterized by** further comprising:

B3. adding the first signal vector V1 and the second signal vector V2 together, to obtain a combined received signal vector V,

wherein the step of mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag in step B comprises: determining the tag distance d between the tag and the reader on the basis of a correlation between tag distance d and combined received signal vector V angle $\theta$.

**2.** A method for locating a tag using a radio frequency identification (RFID) reader, comprising:

A. the reader transmitting a signal to the tag on at least two frequencies and receiving a corresponding reflected signal;
B. subjecting the reflected signal received to a combining operation to obtain a combined received signal, and mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag; wherein the at least two frequencies comprise: a first frequency f1 and a second frequency f2; and the step in which the reader transmits a signal to the tag on at least two frequencies in step A comprises:

the reader generating a first transmission signal $A\cos(2\pi f1*t)$ on first frequency f1, generating a second transmission signal $B\cos(2\pi f2*t)$ on the second frequency f2, and sending a combined transmission signal $A\cos(2\pi f1*t)+B\cos(2\pi f2*t)$ to the tag;
chracterized in that the step of subjecting the reflected signal received to a combining operation to obtain a combined received signal in step B comprises:

the reader mixing the reflected signal received with an I path local oscillator signal $I_{LO} = \frac{\cos(2\pi f1*t)}{H1} + \frac{\sin(2\pi f2*t)}{H2}$, to obtain a combined in-phase component $I_{new}$;
mixing the reflected signal received with a Q path local oscillator signal $Q_{LO} = \frac{\sin(2\pi f1*t)}{H1} + \frac{\cos(2\pi f2*t)}{H2}$, to obtain a combined quadrature component $Q_{new}$;
obtaining the combined received signal on the basis of the combined in-phase component $I_{new}$ and the combined quadrature component $Q_{new}$;
wherein the H1 is a first signal attenuation on the first frequency f1, and the H2 is a second signal attenuation on the second frequency f2 and wherein the step of mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag in step B comprises: determining the tag distance d between the tag and the reader on the basis of a correlation between tag distance d and combined received signal vector V angle $\Theta$.

**3.** The method as claimed in any one of claims 1 - 2, **characterized in that** before step A, it further comprises: C.

setting the first frequency f1 and the second frequency f2, which are different from one another;
after step B, the method further comprises: D. after incrementing the number of tag locating operations performed by 1, determining whether it has reached a preset threshold; if it has, then terminating the process, otherwise changing the first frequency f1
and/or the second frequency f2 to increase the frequency difference therebetween, and returning to step A; or
after step B, the method further comprises: E. comparing the current tag location result with a historical tag location result, and if the difference therebetween is less than a preset threshold, then terminating the process, otherwise changing the first frequency f1 and/or the second frequency f2 to increase the frequency difference therebetween, and returning to step A.

**4.** The method as claimed in claim 1, **characterized in that** the correlation between tag distance d and constellation point vector angle θ is: the vector angle θ of the constellation point is directly proportional to $\frac{2d}{c}(f2-f1)$, wherein c is the speed of light.

**5.** The method as claimed in any one of claims 1 - 2, **characterized by** further comprising: the reader compares the tag distance d of one or more tags with a preset threshold, and reports information about any tag for which the tag distance d is in conformity with the preset threshold to a control center.

**6.** The method as claimed in any one of claims 1 - 2, **characterized in that** the step of mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag in step B comprises:

measuring the tag distance d of the tag at different positions on the first frequency f1 and the second frequency f2;
determining the speed of movement of the tag on the basis of the distance between the positions and the time of movement of the tag;
estimating the path of movement of the tag on the basis of different detected positions and the speed of movement.

**7.** The method as claimed in any one of claims 1 - 2, **characterized by** further comprising: arranging multiple readers to point in different directions, determining the tag distance d between the tag and each reader, and obtaining coordinates of the tag in three dimensions on the basis of the multiple tag distances d.

**8.** The method as claimed in any one of claims 1 - 2, **characterized in that** before step A, it further comprises: the reader measuring the average Received Signal Strength Indication (RSSI) value, and filtering out tags for which the actual RSSI value is less than the average RSSI value.

**9.** A radio frequency identification (RFID) reader, comprising:

a control unit, for directing a frequency generation unit to generate at least two frequencies; a signal transmission unit, for transmitting a signal to a tag on the at least two frequencies generated;
the control unit being configured to subject a reflected signal received by a signal receiving unit to a combining operation to obtain a combined received signal, and to map the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag;

wherein the at least two frequencies comprise: a first frequency f1 and a second frequency f2;
wherein the signal receiving unit is configured to obtain a first received signal on the first frequency f1 at a first time, and to obtain a second received signal on the second frequency f2 at a second time, wherein the first time and the second time are different; and
wherein the control unit is further configured to:

obtain a first in-phase component I1 and a first quadrature component Q1 from the first received signal, to construct a first signal vector V1 = I1 + jQ1;
obtain a second in-phase component 12 and a second quadrature component Q2 from the second received signal, to construct a second signal vector V2 = Q2 + jI2;
**characterized by** the control unit being further configured to add the first signal vector V1 and the second signal vector V2 together, to obtain a combined received signal vector V, and
to determine the tag distance d between the tag and the reader on the basis of a correlation between tag distance

d and combined received signal vector V angle $\theta$ when mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag.

**10.** A radio frequency identification (RFID) reader comprising a control unit, for directing a frequency generation unit to generate at least two frequencies; a signal transmission unit, for transmitting a signal to a tag on the at least two frequencies generated; the control unit being configured to subject a reflected signal received by a signal receiving unit to a combining operation to obtain a combined received signal, and to map the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag; wherein:

the at least two frequencies comprise: a first frequency f1 and a second frequency f2;
the signal transmission unit is used for generating a first transmission signal $A\cos(2\pi f1*t)$ on the first frequency f1, generating a second transmission signal $B\cos(2\pi f2*t)$ on the second frequency f2, and emitting a combined transmission signal $A\cos(2\pi f1*t)+B\cos(2\pi f2*t)$;
the signal receiving unit comprises a first receiving module and a second receiving module;
**characterized in that**:

the first receiving module is used for mixing a signal obtained by a receiving antenna with an I path local oscillator signal $I_{LO} = \frac{\cos(2\pi f1*t)}{H1} + \frac{\sin(2\pi f2*t)}{H2}$, to obtain a combined in-phase component $I_{new}$, and supplies this to the control unit;
the second receiving module is used for mixing a signal obtained by the receiving antenna with a Q path local oscillator signal $Q_{LO} = \frac{\sin(2\pi f1*t)}{H1} + \frac{\cos(2\pi f2*t)}{H2}$, to obtain a combined quadrature component $Q_{new}$, and supplies this to the control unit;

the control unit is used to obtain the combined received signal on the basis of the combined in-phase component $I_{new}$ and the combined quadrature component $Q_{new}$;
wherein the H1 is a first signal attenuation on the first frequency f1, and the H2 is a second signal attenuation on the second frequency f2 and wherein mapping the combined received signal to a constellation point on a constellation diagram for the purpose of locating the tag comprises determining the tag distance d between the tag and the reader on the basis of a correlation between tag distance d and combined received signal vector V angle $\Theta$.

**11.** The reader as claimed in claim 10, **characterized in that** it further comprises: a signal attenuation unit;
the control unit being used for directing the signal transmission unit to transmit a signal on the first frequency f1 to obtain H1 by channel estimation, and directing the signal attenuation unit to generate a first attenuation factor G1 = 1/H1 for the first frequency f1, and for directing the signal transmission unit to transmit a signal on the second frequency f2 to obtain H2 by channel estimation, and directing the signal attenuation unit to generate a second attenuation factor G2 = 1/H2 for the second frequency f2.

**12.** The reader as claimed in any one of claims 9 - 11, **characterized in that** the control unit is further configured to:
directing the frequency generation unit to change the first frequency f1 and/or the second frequency f2, to increase the frequency difference therebetween, and directing the signal transmission unit to transmit a signal to the tag on the first frequency f1 and second frequency f2 after the change.

## Patentansprüche

**1.** Verfahren zum Lokalisieren eines Transponders unter Verwendung eines Radio Frequency Identification (RFTD)-Lesegerätes, umfassend:

A. das Lesegerät sendet ein Signal an den Transponder auf mindestens zwei Frequenzen und empfängt ein entsprechendes reflektiertes Signal;
B. Einspeisen des empfangenen reflektierten Signals in eine Kombinierungsoperation, um ein kombiniertes empfangenes Signal zu erhalten, und Abbilden des kombinierten empfangenen Signals auf einen Konstellati-

onspunkt in einem Konstellationsdiagramm zum Zweck des Lokalisierens des Transponders;

wobei die mindestens zwei Frequenzen eine erste Frequenz f1 und eine zweite Frequenz f2 umfassen; und der Schritt des Empfangens eines entsprechenden reflektierten Signals in Schritt A Folgendes umfasst:

das Lesegerät erhält ein erstes empfangenes Signal auf der ersten Frequenz f1 an einem ersten Zeitpunkt und erhält ein zweites empfangenes Signal auf der zweiten Frequenz f2 an einem zweiten Zeitpunkt, wobei der erste Zeitpunkt und der zweite Zeitpunkt voneinander verschieden sind; und
wobei der Schritt des Einspeisens des empfangenen reflektierten Signals in eine Kombinierungsoperation zum Erhalten eines kombinierten empfangenen Signals in Schritt B Folgendes umfasst:

B1. Erhalten einer ersten phasengleichen Komponente I1 und einer ersten Quadraturkomponente Q1 aus dem ersten empfangenen Signal, um einen ersten Signalvektor V1 = I1 + jQ1 zu konstruieren;
B2. Erhalten einer zweiten phasengleichen Komponente I2 und einer zweiten Quadraturkomponente Q2 aus dem zweiten empfangenen Signal, um einen zweiten Signalvektor V2 = Q2 + jI2 zu konstruieren;

**dadurch gekennzeichnet, dass** es des Weiteren Folgendes umfasst:
B3. Addieren des ersten Signalvektors V1 und des zweiten Signalvektors V2 miteinander zum Erhalten eines kombinierten empfangenen Signalvektors V,
wobei der Schritt des Abbildens des kombinierten empfangenen Signals auf einen Konstellationspunkt in einem Konstellationsdiagramm zum Zweck des Lokalisierens des Transponders in Schritt B Folgendes umfasst:
Bestimmen der Transponderdistanz d zwischen dem Transponder und dem Lesegerät auf der Basis einer Korrelation zwischen der Transponderdistanz d und dem Winkel $\theta$ des kombinierten empfangenen Signalvektors V.

**2.** Verfahren zum Lokalisieren eines Transponders unter Verwendung eines Radio Frequenz Identification (RFID)-Lesegerätes, umfassend:

A. das Lesegerät sendet ein Signal an den Transponder auf mindestens zwei Frequenzen und empfängt ein entsprechendes reflektiertes Signal;
B. Einspeisen des empfangenen reflektierten Signals in eine Kombinierungsoperation zum Erhalten eines kombinierten empfangenen Signals, und Abbilden des kombinierten empfangenen Signals auf einen Konstellationspunkt in einem Konstellationsdiagramm zum Zweck des Lokalisierens des Transponders; wobei die mindestens zwei Frequenzen eine erste Frequenz f1 und eine zweite Frequenz f2 umfassen; und der Schritt, in dem das Lesegerät in Schritt A ein Signal an den Transponder auf mindestens zwei Frequenzen sendet, Folgendes umfasst:

das Lesegerät generiert ein erstes Übertragungssignal $\boldsymbol{A\cos(2\pi f1 * t)}$ auf der ersten Frequenz f1, generiert ein zweites Übertragungssignal $\boldsymbol{B\cos(2\pi f2 * t)}$ auf der zweiten Frequenz f2, und sendet ein kombiniertes Übertragungssignal $\boldsymbol{A\cos(2\pi f1 * t) + B\cos(2\pi f2 * t)}$ an den Transponder;
**dadurch gekennzeichnet, dass** der Schritt des Einspeisens des empfangenen reflektierten Signals in eine Kombinierungsoperation zum Erhalten eines kombinierten empfangenen Signals in Schritt B Folgendes umfasst:

das Lesegerät mischt das empfangene reflektierte Signal mit einem I-Pfad-Überlagerungsoszillator-Signal $I_{LO} = \frac{\cos(2\pi f1 * t)}{H1} + \frac{\sin(2\pi f2 * t)}{H2}$, um eine kombinierte phasengleiche Komponente $I_{new}$ zu erhalten; mischt das empfangene reflektierte Signal mit einem Q-Pfad-Überlagerungsoszillator-Signal $Q_{LO} = \frac{\sin(2\pi f1 * t)}{H1} + \frac{\cos(2\pi f2 * t)}{H2}$, um eine kombinierte Quadraturkomponente $Q_{new}$ zu erhalten;
und erhält das kombinierte empfangene Signal auf der Basis der kombinierten phasengleichen Komponente $I_{new}$ und der kombinierten Quadraturkomponente $Q_{new}$;
wobei das H1 eine erste Signaldämpfung auf der ersten Frequenz f1 ist und das H2 eine zweite Signaldämpfung auf der zweiten Frequenz f2 ist, und wobei der Schritt des Abbildens des kombinierten empfangenen Signals auf einen Konstellationspunkt in einem Konstellationsdiagramm zum Zweck des Lokalisierens des Transponders in Schritt B Folgendes umfasst:

Bestimmen der Transponderdistanz d zwischen dem Transponder und dem Lesegerät auf der Basis einer Korrelation zwischen der Transponderdistanz d und dem Winkel θ des kombinierten empfangenen Signalvektors V.

3. Verfahren nach einem der Ansprüche 1 und 2, **dadurch gekennzeichnet, dass** es vor dem Schritt A des Weiteren Folgendes umfasst:
C. Einstellen der ersten Frequenz f1 und der zweiten Frequenz f2, die voneinander verschieden sind;
wobei das Verfahren nach dem Schritt B des Weiteren Folgendes umfasst:
D. nach dem Inkrementieren der Anzahl ausgeführter Transponderlokalisierungsoperationen um 1, Bestimmen, ob eine voreingestellte Schwelle erreicht wurde; wenn ja, dann Beenden des Prozesses, anderenfalls Ändern der ersten Frequenz f1 und/oder der zweiten Frequenz f2, um die Frequenzdifferenz zwischen beiden zu erhöhen, und Zurückkehren zu Schritt A; oder
das Verfahren nach dem Schritt B des Weiteren Folgendes umfasst:
E. Vergleichen des momentanen Transponderstandortresultats mit einem historischen Transponderstandortresultat und, falls die Differenz zwischen beiden niedriger ist als eine voreingestellte Schwelle, dann Beenden des Prozesses, anderenfalls Ändern der ersten Frequenz f1 und/oder der zweiten Frequenz f2, um die Frequenzdifferenz zwischen beiden zu erhöhen, und Zurückkehren zu Schritt A.

4. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** die Korrelation zwischen der Transponderdistanz d und dem Konstellationspunkt-Vektorwinkel θ folgendermaßen ist: der Vektorwinkel θ des Konstellationspunktes verhält sich direkt proportional zu $\frac{2d}{c}(f2-f1)$, wobei c die Lichtgeschwindigkeit ist.

5. Verfahren nach einem der Ansprüche 1 und 2, **dadurch gekennzeichnet, dass** es des Weiteren umfasst, dass das Lesegerät die Transponderdistanz d eines oder mehrerer Transponder mit einer voreingestellten Schwelle vergleicht und Informationen über jeden Transponder, bei dem die Transponderdistanz d mit der voreingestellten Schwelle übereinstimmt, an eine Steuerungszentrale berichtet.

6. Verfahren nach einem der Ansprüche 1 und 2, **dadurch gekennzeichnet, dass** der Schritt des Abbildens des kombinierten empfangenen Signals auf einen Konstellationspunkt in einem Konstellationsdiagramm zum Zweck des Lokalisierens des Transponders in Schritt B Folgendes umfasst:

Messen der Transponderdistanz d des Transponders an verschiedenen Positionen auf der ersten Frequenz f1 und der zweiten Frequenz f2;
Bestimmen der Bewegungsgeschwindigkeit des Transponders auf der Basis der Distanz zwischen den Positionen und der Bewegungszeit des Transponder; und
Schätzen des Bewegungspfades des Transponders auf der Basis unterschiedlicher detektierter Positionen und der Bewegungsgeschwindigkeit.

7. Verfahren nach einem der Ansprüche 1 und 2, **dadurch gekennzeichnet, dass** es des Weiteren Folgendes umfasst: Anordnen mehrerer Lesegeräte dergestalt, dass sie in verschiedene Richtungen weisen, Bestimmen der Transponderdistanz d zwischen dem Transponder und jedem Lesegerät und Erhalten von Koordinaten des Transponders in drei Dimensionen auf der Basis der mehreren Transponderdistanzen d.

8. Verfahren nach einem der Ansprüche 1 und 2, **dadurch gekennzeichnet, dass** es vor dem Schritt A des Weiteren Folgendes umfasst: das Lesegerät misst den durchschnittlichen Received Signal Strength Indication (RSSI)-Wert und filtert Transponder heraus, bei denen der tatsächliche RSSI-Wert niedriger ist als der durchschnittliche RSSI-Wert.

9. Radio Frequenz Identification (RFID)-Lesegerät, umfassend:

eine Steuereinheit, um eine Frequenzgenerierungseinheit anzuweisen, mindestens zwei Frequenzen zu generieren;
eine Signalsendeeinheit zum Senden eines Signals an einen Transponder auf den generierten mindestens zwei Frequenzen;
wobei die Steuereinheit dafür ausgestaltet ist, ein durch eine Signalempfangseinheit empfangenes reflektiertes Signal einer Kombinierungsoperation zu unterziehen, um ein kombiniertes empfangenes Signal zu erhalten,

und das kombinierte empfangene Signal auf einen Konstellationspunkt in einem Konstellationsdiagramm zum Zweck des Lokalisierens des Transponders abzubilden;
wobei die mindestens zwei Frequenzen eine erste Frequenz f1 und eine zweite Frequenz f2 umfassen;
wobei die Signalempfangseinheit dafür ausgestaltet ist, ein erstes empfangenes Signal auf der ersten Frequenz f1 an einem ersten Zeitpunkt zu erhalten und ein zweites empfangenes Signal auf der zweiten Frequenz f2 an einem zweiten Zeitpunkt zu erhalten, wobei der erste Zeitpunkt und der zweite Zeitpunkt voneinander verschieden sind; und
wobei die Steuereinheit des Weiteren für Folgendes ausgestaltet ist:

Erhalten einer ersten phasengleichen Komponente I1 und einer ersten Quadraturkomponente Q1 aus dem ersten empfangenen Signal, um einen ersten Signalvektor V1 = I1 + jQ1 zu konstruieren;
Erhalten einer zweiten phasengleichen Komponente I2 und einer zweiten Quadraturkomponente Q2 aus dem zweiten empfangenen Signal, um einen zweiten Signalvektor V2 = Q2 + jI2 zu konstruieren;

**dadurch gekennzeichnet, dass** die Steuereinheit des Weiteren für Folgendes ausgestaltet ist:

Addieren des ersten Signalvektors V1 und des zweiten Signalvektors V2 miteinander zum Erhalten eines kombinierten empfangenen Signalvektors V, und
Bestimmen der Transponderdistanz d zwischen dem Transponder und dem Lesegerät auf der Basis einer Korrelation zwischen der Transponderdistanz d und dem Winkel θ des kombinierten empfangenen Signalvektors V, wenn das kombinierte empfangene Signal auf einen Konstellationspunkt in einem Konstellationsdiagramm zum Zweck des Lokalisierens des Transponders abgebildet wird.

**10.** Radio Frequenz Identification (RFID)-Lesegerät, umfassend: eine Steuereinheit, um eine Frequenzgenerierungseinheit anzuweisen, mindestens zwei Frequenzen zu generieren; eine Signalsendeeinheit zum Senden eines Signals an einen Transponder auf den generierten mindestens zwei Frequenzen; wobei die Steuereinheit dafür ausgestaltet ist, ein durch eine Signalempfangseinheit empfangenes reflektiertes Signal einer Kombinierungsoperation zu unterziehen, um ein kombiniertes empfangenes Signal zu erhalten, und das kombinierte empfangene Signal auf einen Konstellationspunkt in einem Konstellationsdiagramm zum Zweck des Lokalisierens des Transponders abzubilden; wobei:

wobei die mindestens zwei Frequenzen eine erste Frequenz f1 und eine zweite Frequenz f2 umfassen;
die Signalsendeeinheit dafür verwendet wird, ein erstes Übertragungssignal $\boldsymbol{A\cos(2\pi f1^*t)}$ auf der ersten Frequenz f1 zu generieren, ein zweites Übertragungssignal $\boldsymbol{B\cos(2\pi 2^*t)}$ auf der zweiten Frequenz f2 zu generieren, und ein kombiniertes Übertragungssignal $\boldsymbol{A\cos(2\pi f1^*t)+B\cos(2\pi 2^*t)}$ auszusenden,
wobei die Signalempfangseinheit ein erstes Empfangsmodul und ein zweites Empfangsmodul umfasst;
**dadurch gekennzeichnet dass**:

das erste Empfangsmodul dafür verwendet wird, ein durch eine Empfangsantenne erhaltenes Signal mit einem I-Pfad-Überlagerungsoszillator-Signal $I_{LO} = \frac{\cos(2\pi f1 * t)}{H1} + \frac{\sin(2\pi f2 * t)}{H2}$ zu mischen, um eine kombinierte phasengleiche Komponente Inew zu erhalten, und dieses an die Steuereinheit übermittelt;
das zweite Empfangsmodul dafür verwendet wird, ein durch die Empfangsantenne erhaltenes Signal mit einem Q-Pfad-Überlagerungsoszillator-Signal $Q_{LO} = \frac{\sin(2\pi f1 * t)}{H1} + \frac{\cos(2\pi f2 * t)}{H2}$ zu mischen, um eine kombinierte Quadraturkomponente $Q_{new}$ zu erhalten, und dieses an die Steuereinheit übermittelt; und
die Steuereinheit dafür verwendet wird, das kombinierte empfangene Signal auf der Basis der kombinierten phasengleichen Komponente Inew und der kombinierten Quadraturkomponente Qnew zu erhalten;

wobei das H1 eine erste Signaldämpfung auf der ersten Frequenz f1 ist und das H2 eine zweite Signaldämpfung auf der zweiten Frequenz f2 ist und wobei das Abbilden des kombinierten empfangenen Signals auf einen Konstellationspunkt in einem Konstellationsdiagramm zum Zweck des Lokalisierens des Transponders Folgendes umfasst:
Bestimmen der Transponderdistanz d zwischen dem Transponder und dem Lesegerät auf der Basis einer Korrelation zwischen der Transponderdistanz d und dem Winkel θ des kombinierten empfangenen Signalvektors V.

**11.** Lesegerät nach Anspruch 10, **dadurch gekennzeichnet, dass** es des Weiteren Folgendes umfasst:

eine Signaldämpfungseinheit;
wobei die Steuereinheit dafür verwendet wird, die Signalsendeeinheit anzuweisen, ein Signal auf der ersten Frequenz f1 zu senden, um H1 durch Kanalschätzung zu erhalten, und die Signaldämpfungseinheit anzuweisen, einen ersten Dämpfungsfaktor G1 = /H1 für die erste Frequenz f1 zu generieren, und die Signalsendeeinheit anzuweisen, ein Signal auf der zweiten Frequenz f2 zu senden, um H2 durch Kanalschätzung zu erhalten, und die Signaldämpfungseinheit anzuweisen, einen zweiten Dämpfungsfaktor G2 = 1/H2 für die zweite Frequenz f2 zu generieren.

**12.** Lesegerät nach einem der Ansprüche 9-11, **dadurch gekennzeichnet, dass** die Steuereinheit des Weiteren für Folgendes ausgestaltet ist:
Anweisen der Frequenzgenerierungseinheit, die erste Frequenz f1 und/oder die zweite Frequenz f2 zu ändern, um die Frequenzdifferenz zwischen beiden zu erhöhen, und Anweisen der Signalsendeeinheit, ein Signal an den Transponder auf der ersten Frequenz f1 und der zweiten Frequenz f2 nach der Änderung zu senden.

## Revendications

**1.** Procédé de localisation d'une étiquette à l'aide d'un lecteur d'identification par radiofréquence (RFID), comprenant les étapes suivantes :

A. le lecteur transmet un signal à l'étiquette sur au moins deux fréquences et reçoit un signal réfléchi correspondant ;
B. soumettre le signal réfléchi reçu à une opération de combinaison pour obtenir un signal reçu combiné, et mettre en correspondance le signal reçu combiné avec un point de constellation sur un diagramme de constellation dans le but de localiser l'étiquette ;

dans lequel lesdites au moins deux fréquences comprennent : une première fréquence f1 et une seconde fréquence f2 ; et l'étape consistant à recevoir un signal réfléchi correspondant à l'étape A comprend l'étape suivante :

le lecteur obtient un premier signal reçu sur la première fréquence f1 à un premier instant et obtient un second signal reçu sur la seconde fréquence f2 à un second instant, le premier instant et le second instant étant différents ; et
dans lequel l'étape consistant à soumettre le signal réfléchi reçu à une opération de combinaison pour obtenir un signal reçu combiné à l'étape B comprend les étapes consistant à :

B1. obtenir une première composante en phase I1 et une première composante en quadrature Q1 à partir du premier signal reçu, pour construire un premier vecteur de signal V1 = I1 + jQ1 ;
B2. obtenir une seconde composante en phase I2 et une seconde composante en quadrature Q2 à partir du second signal reçu, pour construire un second vecteur de signal V2 = Q2 + jI2 ;

**caractérisé en ce qu'**il comprend en outre l'étape consistant à :
B3. additionner le premier vecteur de signal V1 et le second vecteur de signal V2 pour obtenir un vecteur de signal reçu combiné V,
dans lequel l'étape consistant à mettre en correspondance le signal reçu combiné avec un point de constellation sur un diagramme de constellation dans le but de localiser l'étiquette à l'étape B comprend l'étape consistant à :
déterminer la distance d'étiquette d entre l'étiquette et le lecteur sur la base d'une corrélation entre la distance d'étiquette d et l'angle $\theta$ du vecteur de signal reçu combiné V.

**2.** Procédé de localisation d'une étiquette à l'aide d'un lecteur d'identification par radiofréquence (RFID), comprenant les étapes suivantes :

A. le lecteur transmet un signal à l'étiquette sur au moins deux fréquences et reçoit un signal réfléchi correspondant ;
B. soumettre le signal réfléchi reçu à une opération de combinaison pour obtenir un signal reçu combiné, et mettre en correspondance le signal reçu combiné avec un point de constellation sur un diagramme de constellation dans le but de localiser l'étiquette ;

dans lequel lesdites au moins deux fréquences comprennent : une première fréquence f1 et une seconde fréquence f2 ; et l'étape dans laquelle le lecteur transmet un signal à l'étiquette sur au moins deux fréquences à l'étape A comprend l'étape suivante :

le lecteur génère un premier signal de transmission *Acos(2πf 1*t)* sur la première fréquence f1, génère un second signal de transmission *Bcos(2πf 2 *t)* sur la seconde fréquence f2, et envoie un signal de transmission combiné *Acos(2πf 1 * t) + Bcos(2πf 2 * t)* à l'étiquette ;
**caractérisé en ce que**
l'étape consistant à soumettre le signal réfléchi reçu à une opération de combinaison pour obtenir un signal reçu combiné à l'étape B comprend les étapes suivantes :

le lecteur mélange le signal réfléchi reçu avec un signal d'oscillateur local de voie I $I_{LO} = \frac{\cos(2\pi f 1 * t)}{H1} + \frac{\sin(2\pi f 2 * t)}{H2}$, pour obtenir une composante en phase combinée $I_{new}$ ; mélanger le signal réfléchi reçu avec un signal d'oscillateur local de voie Q $Q_{LO} = \frac{\sin(2\pi f 1 * t)}{H1} + \frac{\cos(2\pi f 2 * t)}{H2}$, pour obtenir une composante en quadrature combinée $Q_{new}$ ;
obtenir le signal reçu combiné sur la base de la composante en phase combinée $I_{new}$ et de la composante en quadrature combinée $Q_{new}$ ;
dans lequel H1 est une première atténuation de signal sur la première fréquence f1, et H2 est une seconde atténuation de signal sur la seconde fréquence f2 et dans lequel l'étape consistant à mettre en correspondance avec un point de constellation sur un diagramme de constellation dans le but de localiser l'étiquette à l'étape B comprend l'étape consistant à :
déterminer la distance d'étiquette d entre l'étiquette et le lecteur sur la base d'une corrélation entre la distance d'étiquette d et l'angle θ du vecteur de signal reçu combiné V.

**3.** Procédé selon l'une quelconque des revendications 1 à 2, **caractérisé en ce qu'**avant l'étape A, il comprend en outre l'étape consistant à :
C. fixer la première fréquence f1 et la seconde fréquence f2, qui sont différentes l'une de l'autre ;
après l'étape B, le procédé comprend en outre l'étape consistant à :
D. après avoir incrémenté le nombre d'opérations de localisation d'étiquette effectuées par 1, déterminer s'il a atteint un seuil prédéfini ; si tel est le cas, terminer le processus, sinon modifier la première fréquence f1 et/ou la seconde fréquence f2 pour augmenter la différence de fréquence entre elles, et retourner à l'étape A ; ou
après l'étape B, le procédé comprend en outre l'étape consistant à :
E. comparer le résultat actuel de localisation de l'étiquette avec un résultat historique de localisation de l'étiquette, et si la différence entre les deux est inférieure à un seuil prédéfini, terminer le processus, sinon modifier la première fréquence f1 et/ou la seconde fréquence f2 pour augmenter la différence de fréquence entre elles, et retourner à l'étape A.

**4.** Procédé selon la revendication 1, **caractérisé en ce que** la corrélation entre la distance d'étiquette d et l'angle θ du vecteur de point de constellation est : l'angle vectoriel θ du point de constellation est directement proportionnel à $\frac{2d}{c}(f2 - f1)$, où c est la vitesse de la lumière.

**5.** Procédé selon l'une quelconque des revendications 1 à 2, **caractérisé en ce qu'**il comprend en outre l'étape suivante : le lecteur compare la distance d'étiquette d d'une ou plusieurs étiquettes avec un seuil prédéfini, et rapporte des informations sur toute étiquette pour laquelle la distance d'étiquette d est conforme au seuil prédéfini à un centre de commande.

**6.** Procédé selon l'une quelconque des revendications 1 à 2, **caractérisé en ce que** l'étape consistant à mettre en correspondance le signal reçu combiné avec un point de constellation sur un diagramme de constellation dans le but de localiser l'étiquette à l'étape B comprend les étapes consistant à :

mesurer la distance d'étiquette d de l'étiquette à différentes positions sur la première fréquence f1 et la seconde fréquence f2 ;
déterminer la vitesse de déplacement de l'étiquette sur la base de la distance entre les positions et du temps

de déplacement de l'étiquette ;
estimer la trajectoire de déplacement de l'étiquette sur la base des différentes positions détectées et de la vitesse de déplacement.

**7.** Procédé selon l'une quelconque des revendications 1 à 2, **caractérisé en ce qu'**il comprend en outre les étapes consistant à : arranger de multiples lecteurs pour qu'ils pointent dans des directions différentes, déterminer la distance d'étiquette d entre l'étiquette et chaque lecteur, et obtenir les coordonnées de l'étiquette dans trois dimensions sur la base des multiples distances d'étiquettes d.

**8.** Procédé selon l'une quelconque des revendications 1-2, **caractérisé en ce qu'**avant l'étape A, il comprend en outre l'étape suivante : le lecteur mesure la valeur moyenne de l'indicateur de puissance du signal reçu (Received Signal Strength Indication, RSSI), et élimine les étiquettes pour lesquelles la valeur RSSI réelle est inférieure à la valeur RSSI moyenne.

**9.** Lecteur d'identification par radiofréquence (RFID), comprenant :

une unité de commande, pour ordonner à une unité de génération de fréquence de générer au moins deux fréquences ;
une unité de transmission de signal, pour transmettre un signal à une étiquette sur lesdites au moins deux fréquences générées ;
l'unité de commande étant configurée pour soumettre un signal réfléchi reçu par une unité de réception de signal à une opération de combinaison pour obtenir un signal reçu combiné, et pour mettre en correspondance le signal reçu combiné avec un point de constellation sur un diagramme de constellation dans le but de localiser l'étiquette ;
dans lequel lesdites au moins deux fréquences comprennent : une première fréquence f1 et une seconde fréquence f2 ;
dans lequel l'unité de réception de signal est configurée pour obtenir un premier signal reçu sur la première fréquence f1 à un premier instant, et pour obtenir un second signal reçu sur la seconde fréquence f2 à un second instant, le premier instant et le second instant étant différents ; et
dans lequel l'unité de commande est en outre configurée pour :

obtenir une première composante en phase I1 et une première composante en quadrature Q1 à partir du premier signal reçu, pour construire un premier vecteur de signal $V1 = I1 + jQ1$ ;
obtenir une seconde composante en phase I2 et une seconde composante en quadrature Q2 à partir du second signal reçu, pour construire un second vecteur de signal $V2 = Q2 + j12$ ;
**caractérisé en ce que**
l'unité de commande est en outre configurée pour additionner le premier vecteur de signal V1 et le second vecteur de signal V2, pour obtenir un vecteur de signal reçu combiné V, et pour déterminer la distance d'étiquette d entre l'étiquette et le lecteur sur la base d'une corrélation entre la distance d'étiquette d et l'angle $\theta$ du vecteur de signal reçu combiné V lors de la mise en correspondance du signal reçu combiné avec un point de constellation sur un diagramme de constellation dans le but de localiser l'étiquette.

**10.** Lecteur d'identification par radiofréquence (RFID) comprenant une unité de commande, pour ordonner à une unité de génération de fréquence de générer au moins deux fréquences ; une unité de transmission de signal, pour transmettre un signal à une étiquette sur lesdites au moins deux fréquences générées ; l'unité de commande étant configurée pour soumettre un signal réfléchi reçu par une unité de réception de signal à une opération de combinaison pour obtenir un signal reçu combiné, et pour mettre en correspondance le signal reçu combiné avec un point de constellation sur un diagramme de constellation dans le but de localiser l'étiquette ; dans lequel :

lesdites au moins deux fréquences comprennent : une première fréquence f1 et une seconde fréquence f2 ;
l'unité de transmission de signal est utilisée pour générer un premier signal de transmission $A\cos(2\pi f 1 {*} t)$ sur la première fréquence f1, générer un second signal de transmission $B\cos(2\pi f 2 {*} t)$ sur la seconde fréquence f2, et émettre un signal de transmission combiné $A\cos(2\pi f 1 {*} t) + B\cos(2\pi f 2 {*} t)$ ;
l'unité de réception de signal comprend un premier module de réception et un second module de réception ;
**caractérisé en ce que** :

le premier module de réception est utilisé pour mélanger un signal obtenu par une antenne de réception

avec un signal d'oscillateur local de voie I $I_{LO} = \frac{\cos(2\pi f1 * t)}{H1} + \frac{\sin(2\pi f2 * t)}{H2}$ , pour obtenir une composante en phase combinée $I_{new}$, et fournit celle-ci à l'unité de commande ;
le second module de réception est utilisé pour mélanger un signal obtenu par l'antenne de réception avec un signal d'oscillateur local de voie Q $Q_{LO} = \frac{\sin(2\pi f1 * t)}{H1} + \frac{\cos(2\pi f2 * t)}{H2}$ pour obtenir une composante en quadrature combinée $Q_{new}$, et fournit celle-ci à l'unité de commande ;
l'unité de commande est utilisée pour obtenir le signal reçu combiné sur la base de la composante en phase combiné $I_{new}$ et de la composante en quadrature combinée $Q_{new}$ ;
dans lequel H1 est une première atténuation de signal sur la première fréquence f1 et H2 est une seconde atténuation de signal sur la seconde fréquence f2 et dans lequel la mise en correspondance du signal reçu combiné avec un point de constellation sur un diagramme de constellation dans le but de localiser l'étiquette comprend l'étape consistant à déterminer la distance d'étiquette d entre l'étiquette et le lecteur sur la base d'une corrélation entre la distance d'étiquette d et l'angle $\theta$ du vecteur de signal reçu combiné V.

**11.** Lecteur selon la revendication 10, **caractérisé en ce qu'**il comprend en outre :

une unité d'atténuation de signal ;
l'unité de commande étant utilisée pour ordonner à l'unité de transmission de signal de transmettre un signal sur la première fréquence f1 pour obtenir H1 par estimation de canal, et ordonner à l'unité d'atténuation de signal de générer un premier facteur d'atténuation G1 = 1/H1 pour la première fréquence f1, et pour ordonner à l'unité de transmission de signal de transmettre un signal sur la seconde fréquence f2 pour obtenir H2 par estimation de canal, et ordonner à l'unité d'atténuation de signal de générer un second facteur d'atténuation G2 = 1/H2 pour la seconde fréquence f2.

**12.** Lecteur selon l'une quelconque des revendications 9 à 11,
**caractérisé en ce que** l'unité de commande est en outre configurée pour :
ordonner à l'unité de génération de fréquence de modifier la première fréquence f1 et/ou la seconde fréquence f2, pour augmenter la différence de fréquence entre elles, et ordonner à l'unité de transmission de signal de transmettre un signal à l'étiquette sur la première fréquence f1 et la seconde fréquence f2 après la modification.

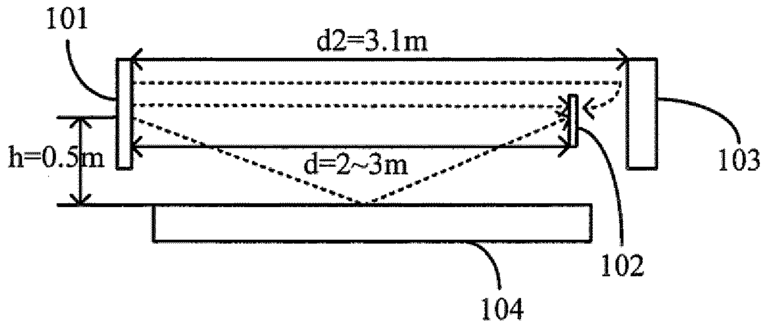
101
d2=3.1m
h=0.5m
d=2~3m
103
102
104

Fig. 1

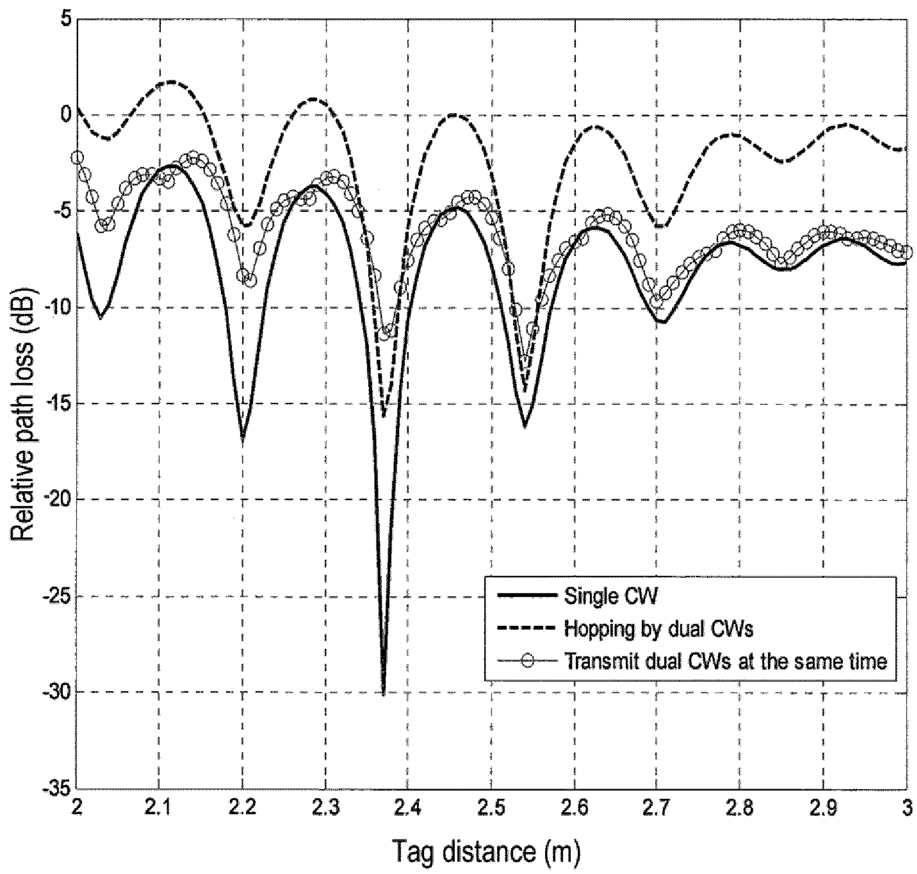
5
0
-5
-10
-15
-20
-25
-30
-35
Relative path loss (dB)
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3
Tag distance (m)
Single CW
Hopping by dual CWs
Transmit dual CWs at the same time

Fig. 2

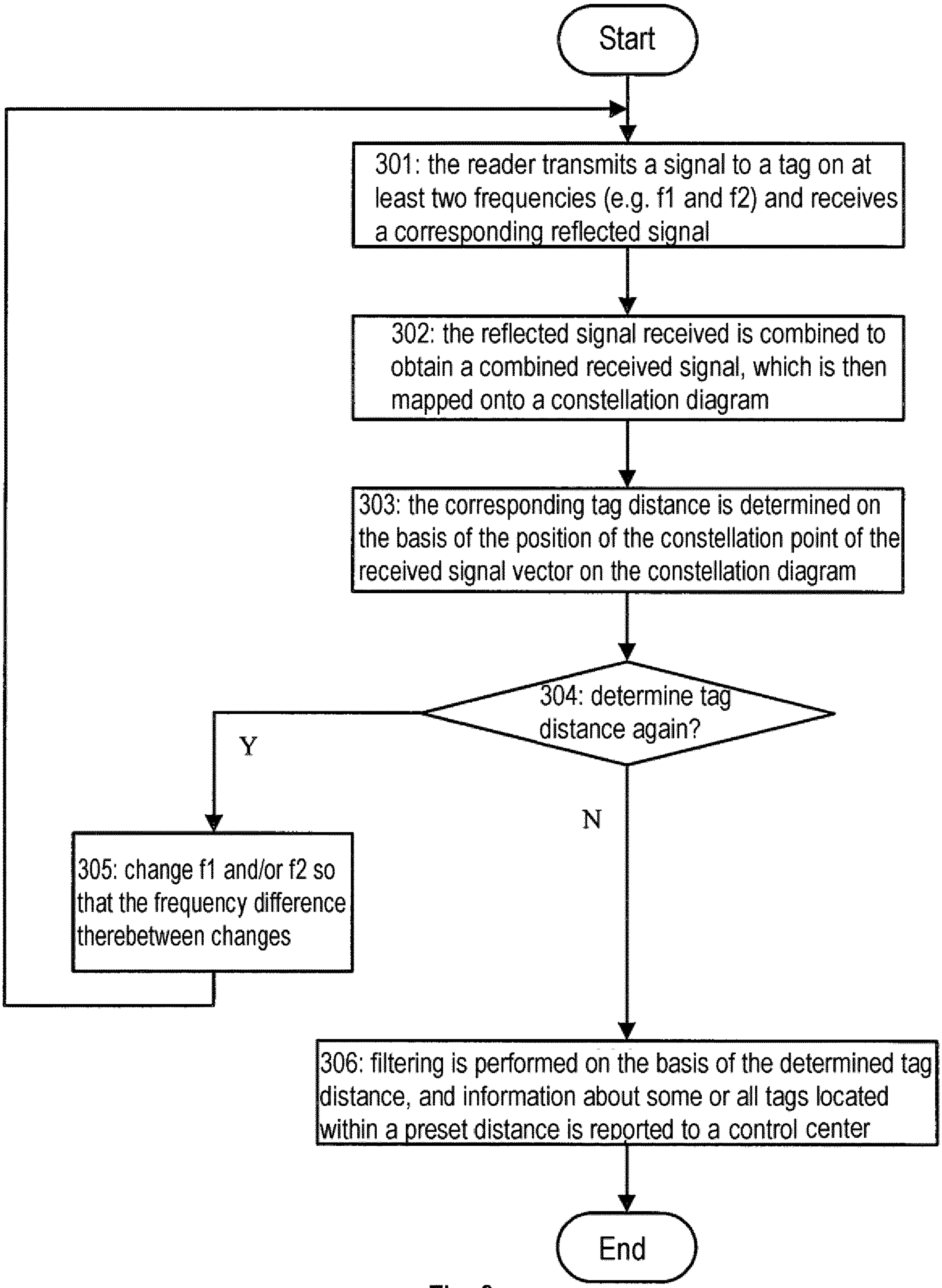
Start
301: the reader transmits a signal to a tag on at least two frequencies (e.g. f1 and f2) and receives a corresponding reflected signal
302: the reflected signal received is combined to obtain a combined received signal, which is then mapped onto a constellation diagram
303: the corresponding tag distance is determined on the basis of the position of the constellation point of the received signal vector on the constellation diagram
304: determine tag distance again?
Y
N
305: change f1 and/or f2 so that the frequency difference therebetween changes
306: filtering is performed on the basis of the determined tag distance, and information about some or all tags located within a preset distance is reported to a control center
End

Fig. 3

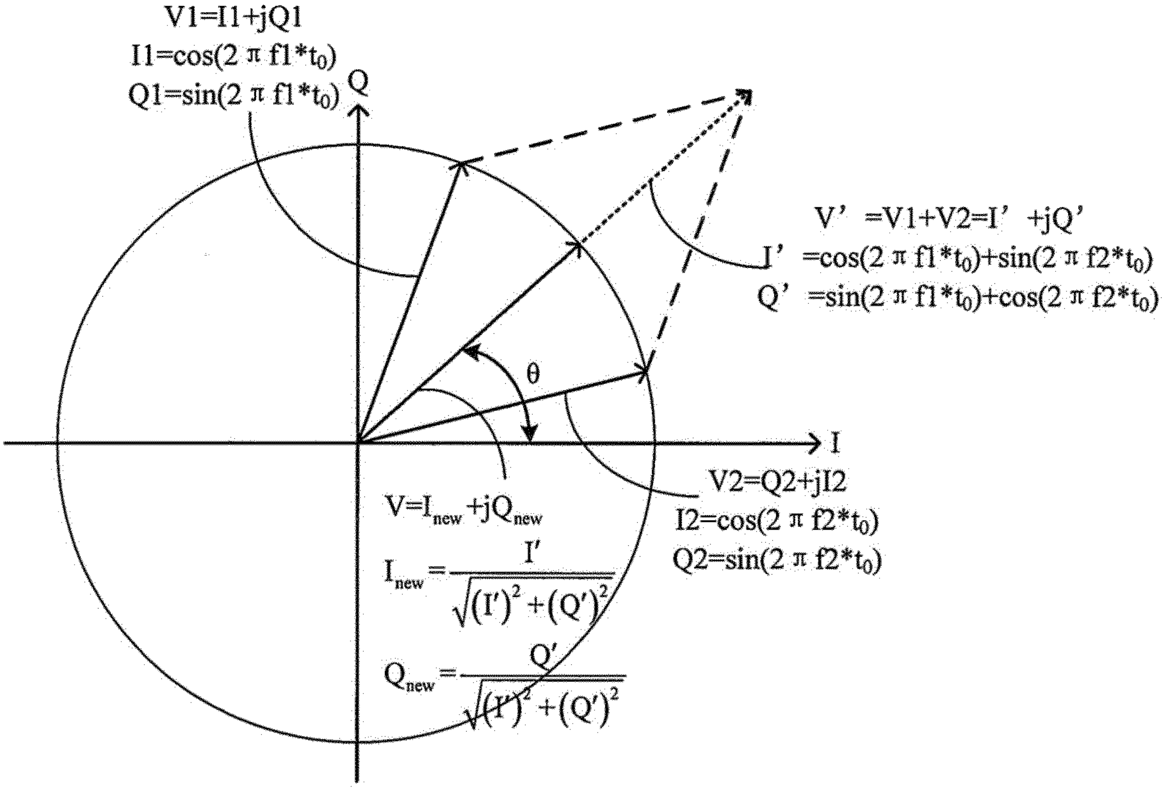
V1=I1+jQ1
I1=cos(2 π f1*t0)
Q1=sin(2 π f1*t0)
Q
V' =V1+V2=I' +jQ'
I' =cos(2 π f1*t0)+sin(2 π f2*t0)
Q' =sin(2 π f1*t0)+cos(2 π f2*t0)
θ
I
V2=Q2+jI2
I2=cos(2 π f2*t0)
Q2=sin(2 π f2*t0)
V=Inew +jQnew
Inew = I' / √((I')² + (Q')²)
Qnew = Q' / √((I')² + (Q')²)

Fig. 4

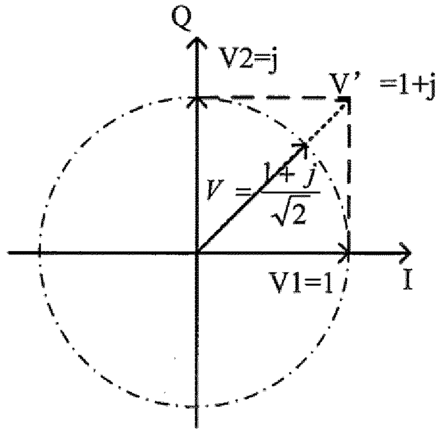


Fig. 5 (a)

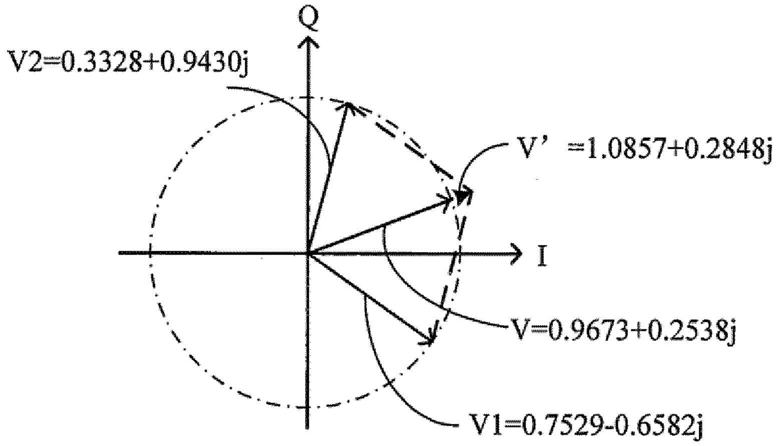


Fig. 5 (b)

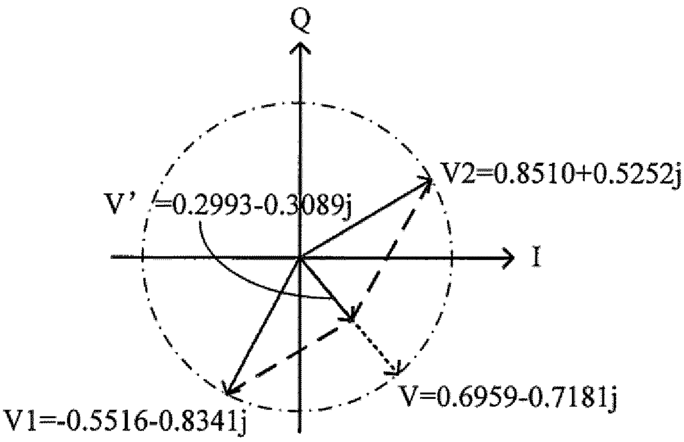


Fig. 5 (c)

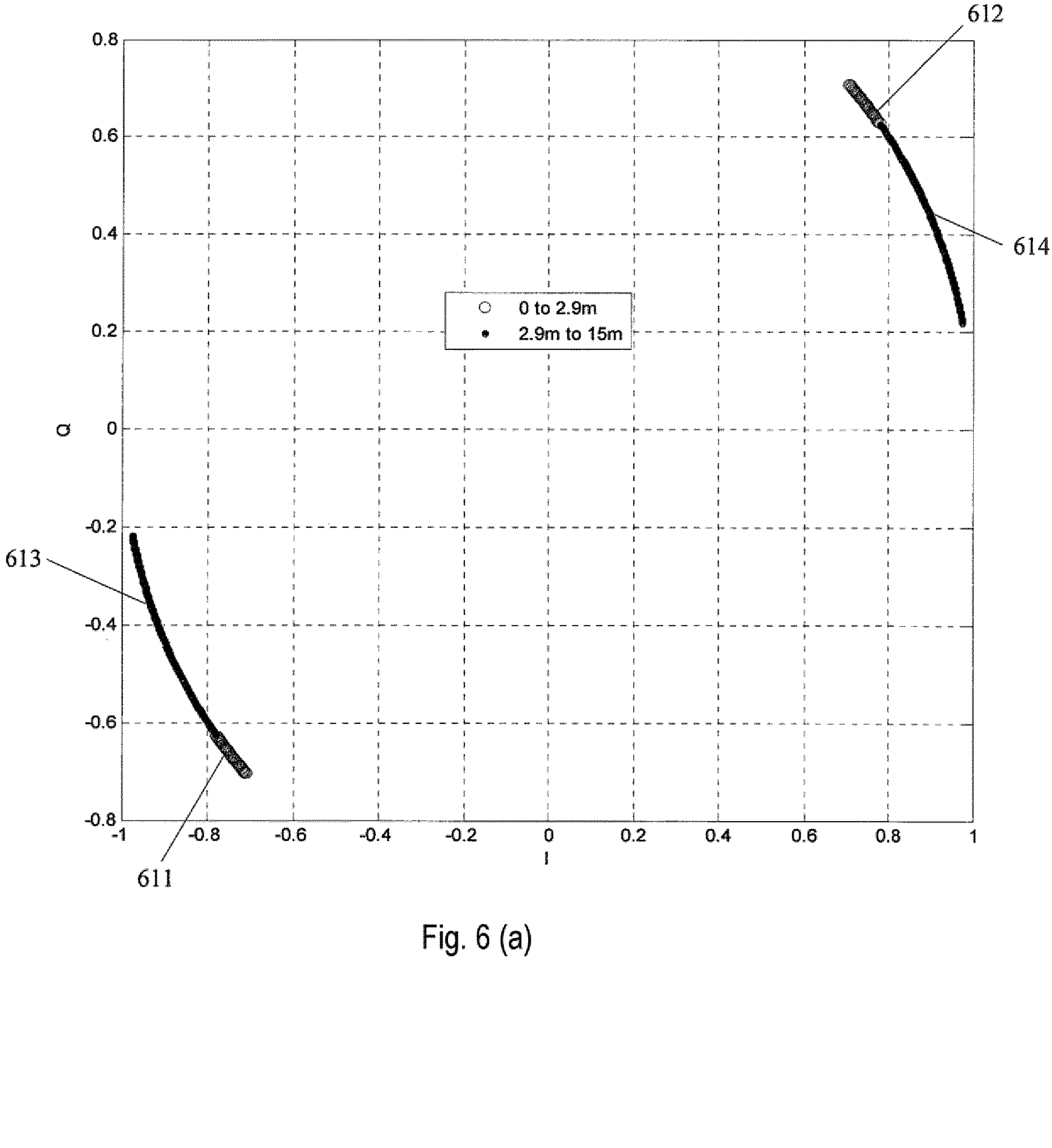
612
614
613
611
0 to 2.9m
2.9m to 15m
Q
I
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

Fig. 6 (a)

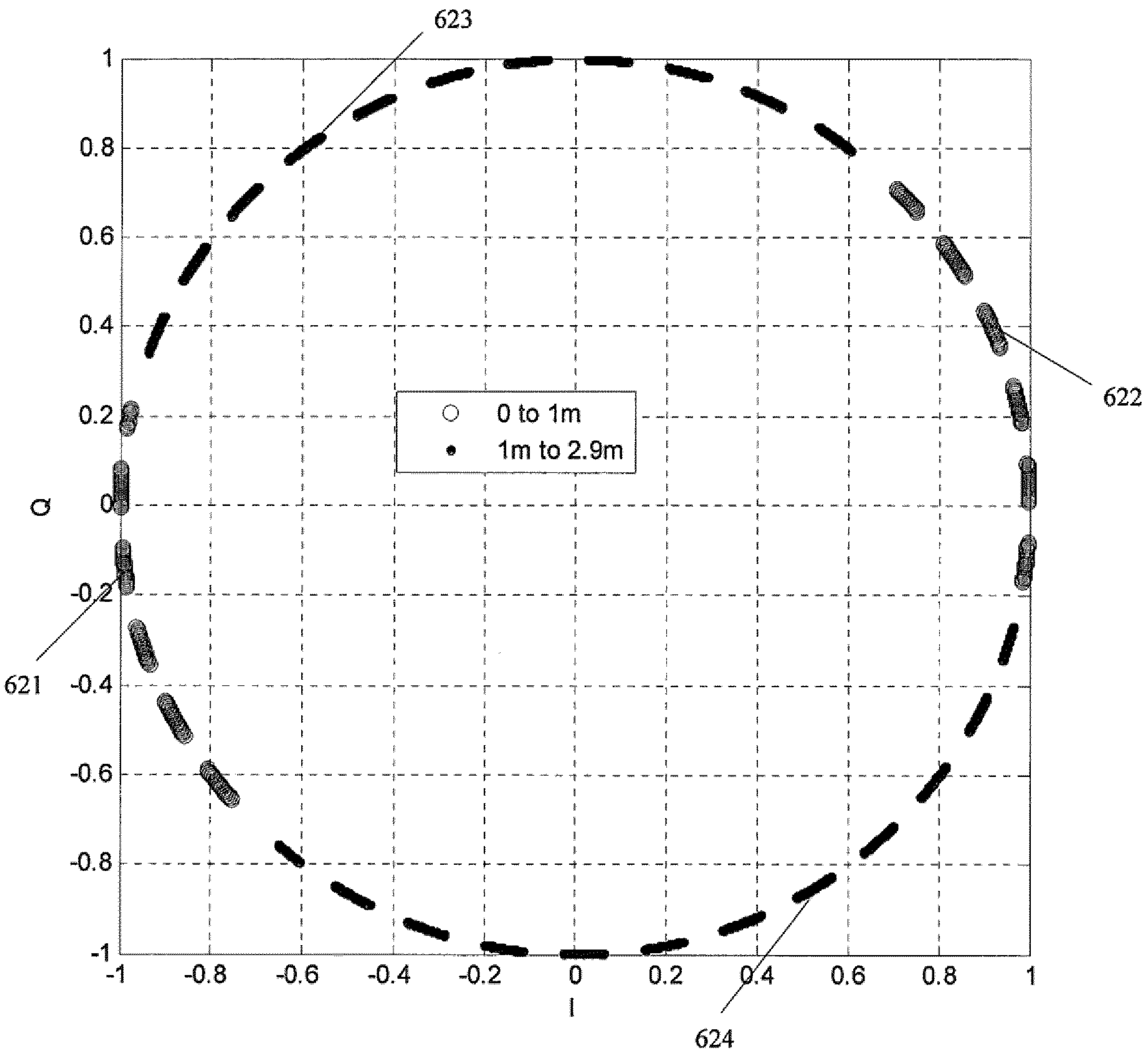
623
622
621
624
0 to 1m
1m to 2.9m
Q
I
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

Fig. 6 (b)

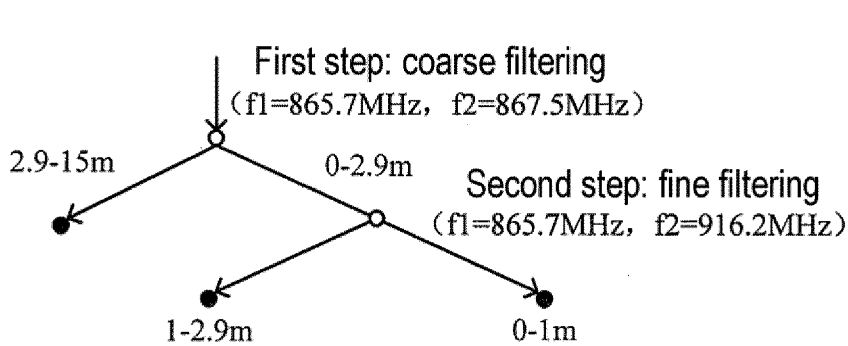
First step: coarse filtering
(f1=865.7MHz, f2=867.5MHz)
2.9-15m
0-2.9m
Second step: fine filtering
(f1=865.7MHz, f2=916.2MHz)
1-2.9m
0-1m

Fig. 7

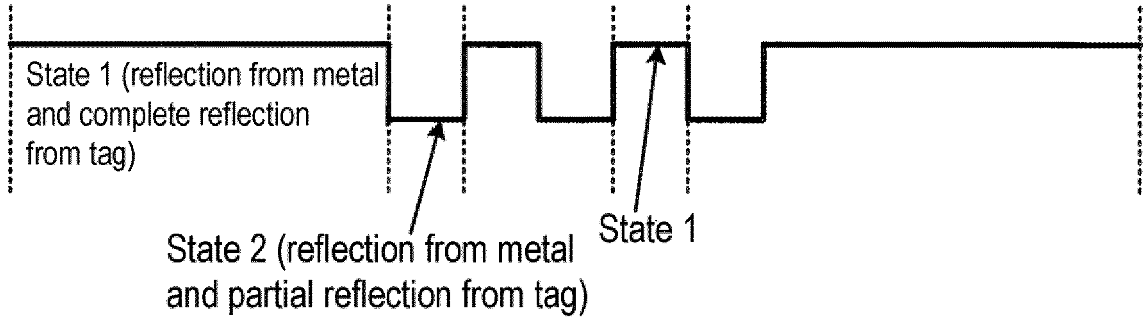
State 1 (reflection from metal and complete reflection from tag)
State 2 (reflection from metal and partial reflection from tag)
State 1

Fig. 8

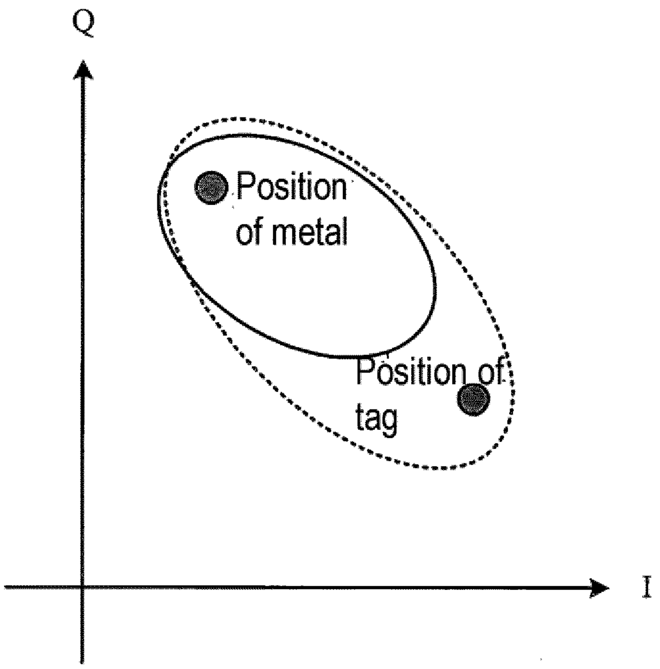
Q
Position of metal
Position of tag
I

Fig. 9

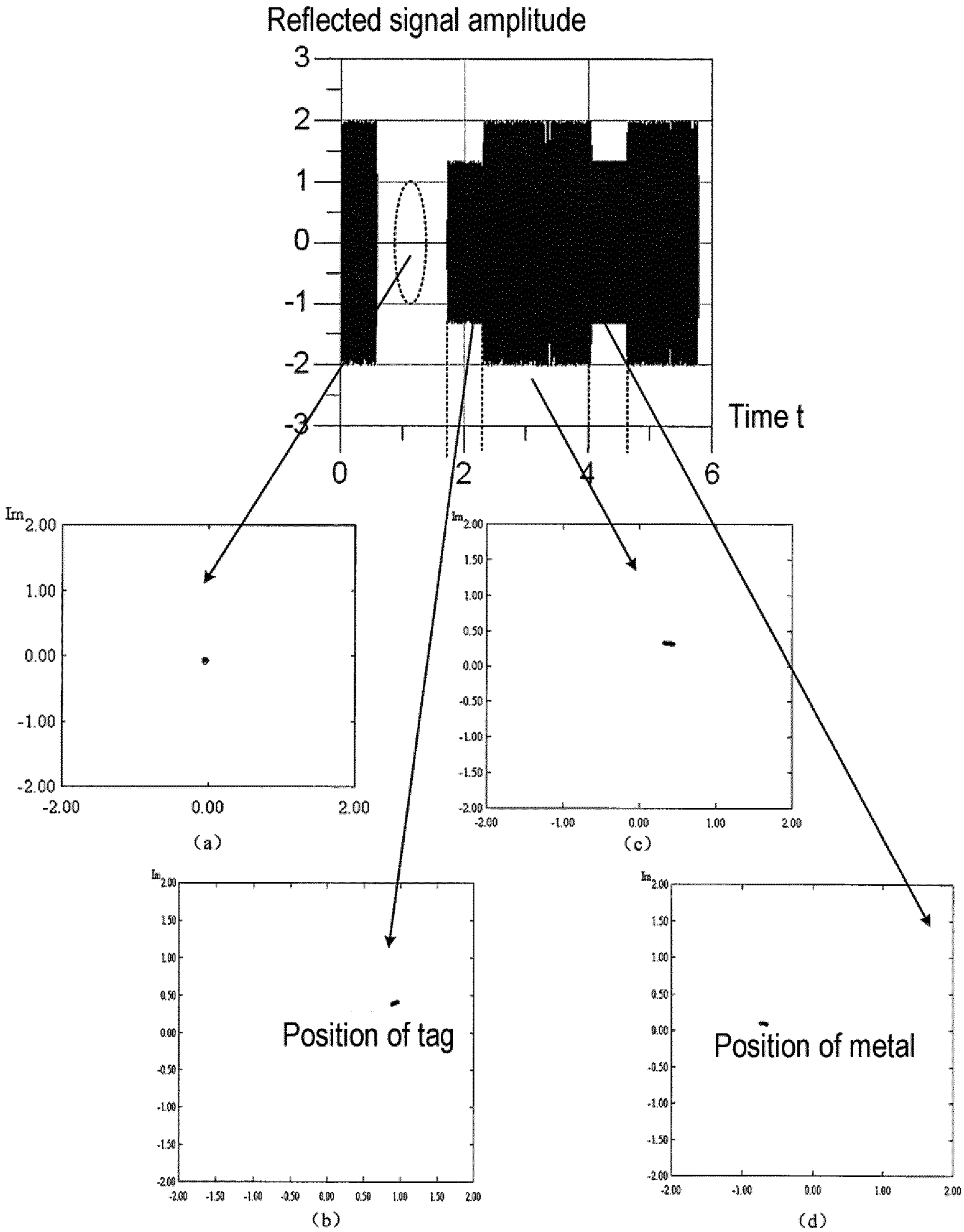
Reflected signal amplitude
Time t
Im
(a)
(b)
(c)
(d)
Position of tag
Position of metal

Fig. 10

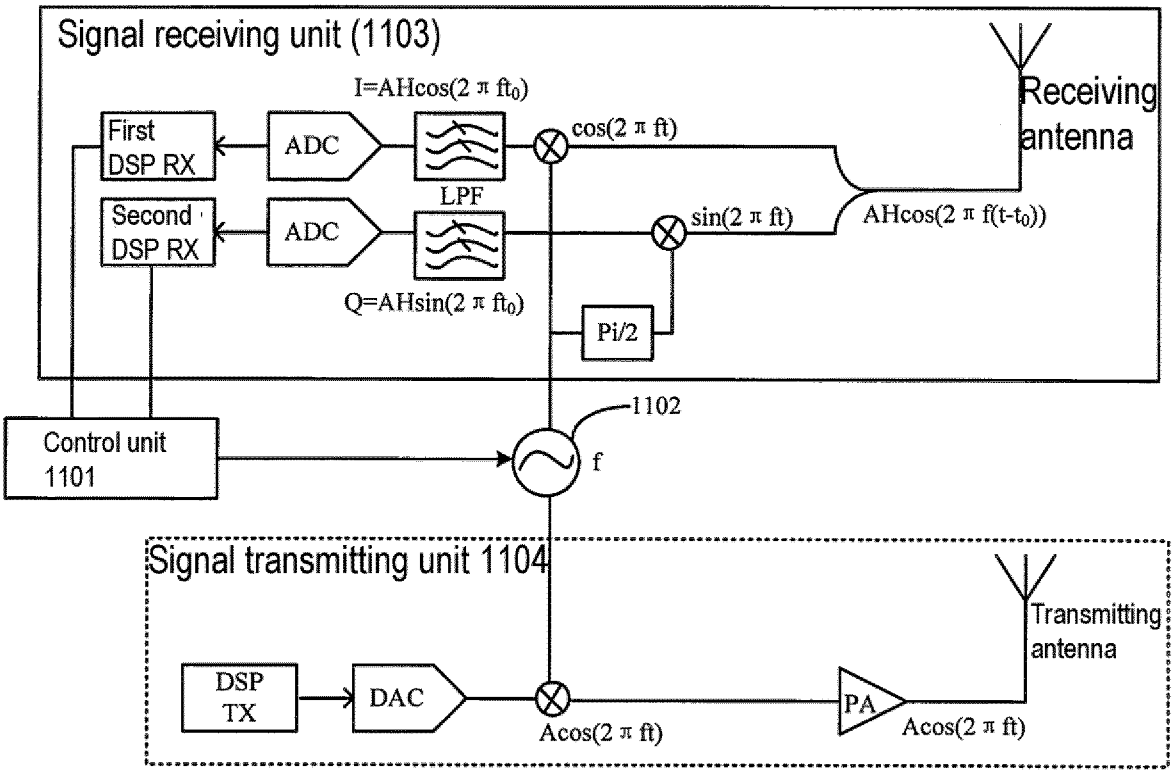
Signal receiving unit (1103)
I=AHcos(2 π ft0)
First DSP RX
ADC
cos(2 π ft)
Receiving antenna
LPF
Second DSP RX
ADC
sin(2 π ft)
AHcos(2 π f(t-t0))
Q=AHsin(2 π ft0)
Pi/2
1102
Control unit 1101
f
Signal transmitting unit 1104
Transmitting antenna
DSP TX
DAC
PA
Acos(2 π ft)
Acos(2 π ft)

Fig. 11

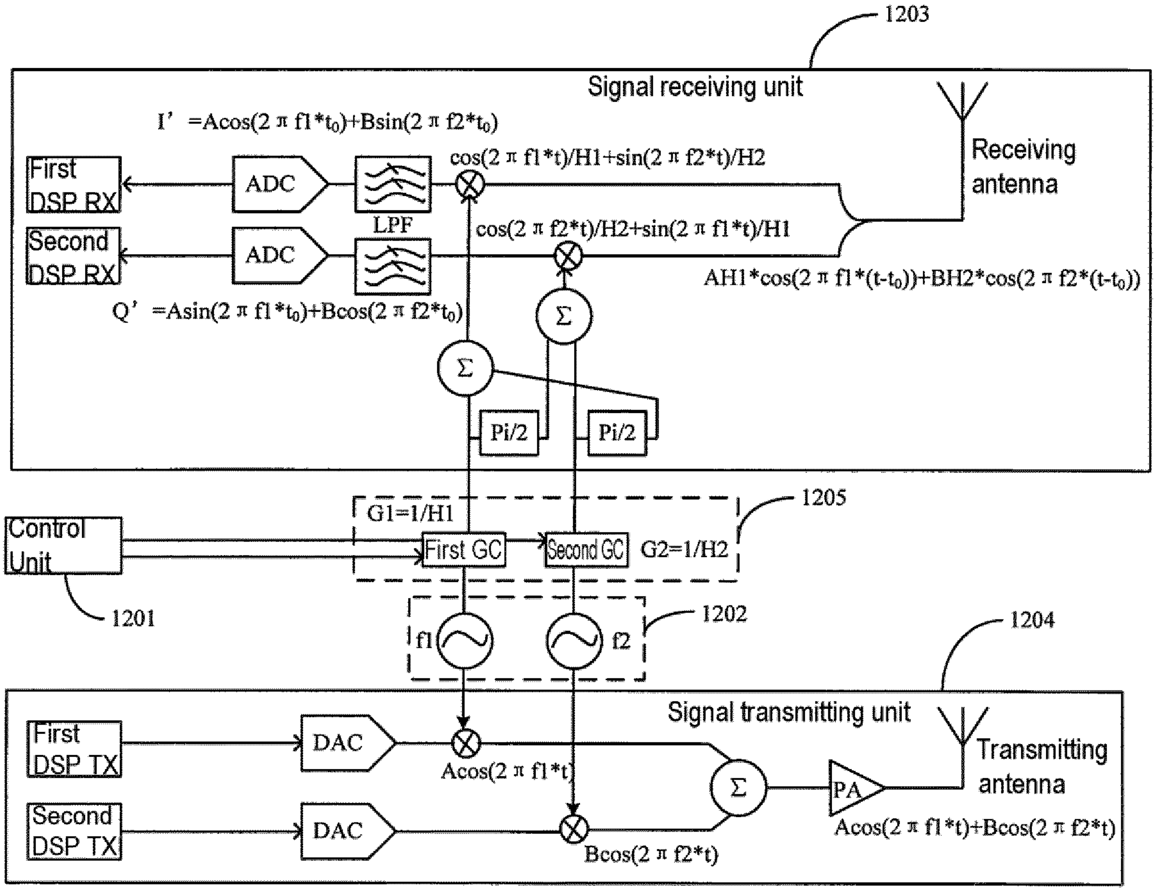
1203
Signal receiving unit
I' =Acos(2 π f1*t₀)+Bsin(2 π f2*t₀)
First DSP RX
ADC
cos(2 π f1*t)/H1+sin(2 π f2*t)/H2
Receiving antenna
LPF
Second DSP RX
ADC
cos(2 π f2*t)/H2+sin(2 π f1*t)/H1
AH1*cos(2 π f1*(t-t₀))+BH2*cos(2 π f2*(t-t₀))
Q' =Asin(2 π f1*t₀)+Bcos(2 π f2*t₀)
Σ
Σ
Pi/2
Pi/2
Control Unit
G1=1/H1
First GC
Second GC
G2=1/H2
1205
1201
f1
f2
1202
1204
Signal transmitting unit
First DSP TX
DAC
Acos(2 π f1*t)
Transmitting antenna
Σ
PA
Second DSP TX
DAC
Acos(2 π f1*t)+Bcos(2 π f2*t)
Bcos(2 π f2*t)

Fig. 12

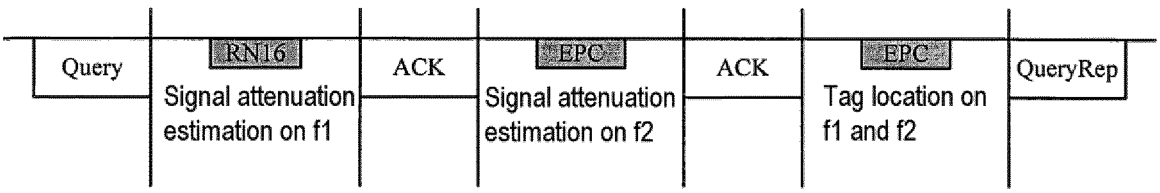
Query
RN16
Signal attenuation estimation on f1
ACK
EPC
Signal attenuation estimation on f2
ACK
EPC
Tag location on f1 and f2
QueryRep

Fig. 13

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- US 20070241904 A1 **[0005]**
- US 20080198903 A1 **[0005]**
- CN 0160421 A **[0005]**
- US 20080048867 A1 **[0005]**